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FINAL REPORT

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"DOWNER COW SYNDROME " IN BEEF COWS FED WINTERING RATIONS BASED ON GREEN FEED

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DOWNER COW SYNDROME IN BEEF COWS FED WINTERING RATIONS BASED ON GREEN FEED

FINAL REPORT

TO THE

SASKATCHEWAN BEEF INDUSTRY DEVELOPMENT FUND

Project # 2002000005 – B053

By

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TABLE OF CONTENTS

LIST OF TABLES iv
LIST OF FIGURES v
LIST OF ABBREVIATIONS vii
Executive Summary vii
1.0 Introduction 1
2.0 Literature Review 3
2.1 Metabolic diseases involving tetany 3
2.1.1 Hypomagnesemic Tetany 3
2.1.1.1. Symptoms 3
2.1.1.2 Predisposing factors 4
2.1.2. Milk Fever 6
2.1.2.1. Symptoms 6
2.1.2.2 Predisposing factors 8
2.1.2.3. Treatment and Prevention. 9
2.2 Metabolic role of electrolytes 10
2.2.1 Potassium 10
2.2.1.1 Metabolic Function. 10
2.2.1.2. Body Requirements. 11
2.2.1.3. Sources 12
2.2.2 Magnesium 13
2.2.2.1. Metabolic Function. 13
2.2.2.2. Body Requirements. 13
2.2.2.3. Sources 15
2.2.3 Calcium 16
2.2.3.1. Metabolic Function. 16
2.2.3.2. Body requirements. 16
2.2.3.3. Sources. 18
2.2.4 Phosphorus 18
2.2.4.3. Sources. 19
2.3 Interaction of electrolytes 20
2.3.1 Calcium:Phosphorus Ratio 21
2.3.2 Dietary Cation-Anion Balance 22
2.3.3 Tetany Ratio 25
2.3.4 Factors affecting mineral absorption 27
2.4 Concentrations of Major Minerals in Forages 30
2.4.1 Characteristics of Major Forages 30
2.4.1.1 Legumes 30
2.4.1.2 Cereals/Grasses 31
2.4.2 Plant Uptake of Potassium 31
2.4.2.1. Fertilizer/Manure 32
2.4.2.2 Temperature 33
2.4.2.3 Forage Maturity 34

2.4.2.4 Soil Characteristics 34
2.5 Conclusion 35
3.0 Case Study of Beef Cows Affected with Tetany-like Symptoms in Five Producer Herds in West-Central Saskatchewan 37
3.1 Introduction 37
3.1 Materials and Methods 42
3.2.1 Data Collection 42
3.2 Results and Discussion 43
3.2.1 Feed Ration Analysis 43
3.2.2 Blood Analysis 47
3.3 Conclusion 53
4.0 Research Project 57
4.1 Introduction 57
4.2 Materials and Methods 57
4.2.1 Treatments 57
4.2.2 Steers 59
4.2.3 Data Collection and Analysis 60
4.2 Results and Discussion 61
4.3 Conclusion 68
5.0 Summary 69
6.0 References 72
APPENDIX A 78
APPENDIX B 83

LIST OF TABLES

Table 2.1 Molecular weights, equivalent weights and conversions from percentages to milliequivalents per kilogram of anions and cations used in the calcultion of 24

Table 3.1 Percent calcium, magnesium and potassium content (DM basis) of greenfeed samples taken from five trial farms. 44

Table 3.2 Mineral content of total dry cow rations (winter 2002) in five producer herds, expressed as percentages of total ration and total weight consumed /head/day. 44

Table 3.3 Ca:P ratio, DCAB and K/[Ca+Mg] ratios in the diets of gestating cows (winter 2002-02) in five producer herds in the North Battleford area, expressed on dry matter basis and including water minerals. 45

Table 3.4 Water analysis from five producer farms in the North Battleford area. 46

Table 3.5 Comparison of blood serum electrolyte levels in affected and non-affected cows 51

Table 3.6 Comparison of blood serum electrolytes in young (<3 years), mature (>3 years) and affected animals. 53

Table 4.1 Pellet composition of experimental diets 59

Table 4.2 Mineral composition of total experimental diets (including both hay and pellet) expressed as a percentage and as gram per head per day. 59

Table 4.3 Ca:P, DCAB and K/(Ca+Mg) ratios of four experimental treatment diets. 59

Table 4.4 Statistical results of repeated measures analysis indicating the effect of tetany ratio on blood serum electrolytes of beef steers. 64

LIST OF FIGURES

Figure 2.1 Flow and excretion of magnesium in the cow (Elliott, 1999)..... 15

Figure 2.2 Mineral Interrelationships (Leeson and Summers, 2001)..... 20

Figure 3.1 Comparison of serum calcium levels in affected cows with the normal range. 47

Figure 3.2 Comparison of average serum calcium levels in groups of affected and unaffected animals from five different herds. 47

Figure 3.3 Comparison of serum phosphorus levels in affected cows with the normal range. 47

Figure 3.4 Comparison of average levels of serum phosphorus in affected and unaffected animals..... 47

Figure 3.5 Comparison of serum levels of magnesium in affected cows with the normal range. 48

Figure 3.6 Comparison of average serum magnesium levels in affected and unaffected animals from five different herds. 48

Figure 3.7 Comparison of serum levels of potassium in affected cows with the normal range. 48

Figure 3.8 Comparison of average serum levels of potassium in affected and unaffected animals from five different herds. 48

Figure 3.9 Comparison of average serum levels of glucose in affected and unaffected animals from five different herds. 49

Figure 3.10 Comparison of average anion gap in affected and unaffected animals from five different herds. 49

Figure 3.11 Comparison of average levels of serum creatinine in affected and unaffected animals from five different herds. 49

Figure 4.1 The effect of tetany ratio on serum electrolyte levels. * significant effect of time ($P < 0.01$); ** significant effect of time ($P < 0.001$); $^{\alpha}$ significant treatment effect ($P < 0.01$) ;$^{\beta}$ significant time x treatment interaction ($P < 0.05$). 63

LIST OF ABBREVIATIONS

$1,25(OH)_2D_3$ – 1,25-dihydroxyvitamin D_3
Ca – Calcium
CSF – Cerebrospinal Fluid
DCAB – Dietary Cation-Anion Balance
DM – Dry matter
GIT – Gastrointestinal Tract
K – Potassium
Mg - Magnesium
P - Phosphorus
PTH – Parathyroid Hormone

Executive Summary

Metabolic diseases which occur at or near parturition including milk fever and hypomagnesemic tetany (grass tetany), can represent a significant economic cost to beef cattle producers. In the winter of 2001-2002, an unusual increase in the number of cows affected with tetany-like symptoms was observed by veterinarians in west-central Saskatchewan. A case study was carried out in order to investigate the nature of the observed disease and to determine if the increased incidence was correlated with nutritional factors, especially high potassium in the dry cow rations. The project was funded by the Saskatchewan Beef Development Fund and run in cooperation with Saskatchewan Agriculture and Food (Mr. Bryan Doig, P.Ag. and Mr. Murray Feist, P.Ag.), Lakeland Veterinary Services Ltd. (Dr. Tom Schmidt) and the University of Saskatchewan (Amanda Walker, Drs. John McKinnon and John Campbell). The objectives as per the project proposal were to:

1. Conduct a comprehensive literature review on grass tetany and milk fever as it relates to beef cattle.
2. Conduct a case study that involved working with a selected number of beef producers (5 to 6) in the northwest region of Saskatchewan to identify what factors led to the development of tetany-like problems in the cooperating herds.
3. Conduct a metabolism trial at the University of Saskatchewan feedlot to study what happens to blood serum minerals such as magnesium and calcium when the tetany ratio of the diet is altered through dietary manipulation.

The project was used by Miss Amanda Walker, a 3rd year student in the College of Agriculture who used the data as a basis for her 4th year senior thesis. This report is based on Miss Walker's thesis.

The case study involved working with 5 separate herds that were affected by tetany-like problems in cows approaching calving during the spring of 2002. Analysis of blood samples from affected and unaffected animals in the five herds as well as feed samples were carried out. All rations were composed primarily of cereal greenfeed. Most of the affected animals exhibited low serum calcium and/or phosphorus. Serum magnesium levels were within the normal range as was the dietary tetany ratio. It was concluded that these cows were suffering from hypocalcemia or milk fever caused by a high dietary cation-anion balance in the ration. A feed trial was also carried out in order to determine the relationship between potassium content of the ration and serum electrolytes in beef steers. The effects of varying the tetany ratio [K/(Ca + Mg)] of the diet was also studied. The experimental diets did not predispose the steers to hypomagnesemia or hypocalcemia, however, the results indicated that there was a significant ($P<0.05$) negative correlation between the tetany ratio of the diet and serum magnesium levels. This may have important implications for feeding management of mature, lactating cows at or shortly after calving.

The conclusions of this work include:

1. The tetany-like symptoms observed in 5 beef herds in northwest Saskatchewan in the spring of 2002 appear to be a result of hypocalcemia induced by dietary factors that led to a high dietary cation anion balance prior to calving.
2. The high dietary cation anion balance was the result of high potassium levels in the green-feed which comprised the bulk of the pre-partum rations.

3. Manipulating the potassium level of diets fed to steers did not markedly alter serum electrolyte levels, although magnesium levels were reduced in a linear fashion in response to increasing tetany ratio in the diet. These results have significant implications for cows approaching calving who are under more metabolic stress to mobilize calcium than the steers used in the study.

4. More research is required to investigate the influence of varying electrolyte levels in the diet such as that of potassium and their effect on metabolic diseases such as milk fever in beef cows.

5. In particular research is required to investigate the relationship between dietary cation anion balance and milk fever in pregnant beef cows.

The author's would like to express appreciation to the 5 cooperating cow herds in the north-west region of Saskatchewan for assisting with this work. The herd and feed information from these individuals formed the basis for this case study. Drs. B. O'Conner and O. Radostits are also thanked for their assistance with interpretation of the results. Appreciation is also expressed to the Saskatchewan Beef Industry Development Fund for financial assistance in conducting the work.

1.0 Introduction

Tetany in cattle is characterized by a variety of symptoms including nervousness, stiff gait, staggering, convulsions and paralysis. The cause of the disorder is often complex, but usually involves abnormalities and alterations in the levels and ratios of blood serum electrolytes within the animal. There are several metabolic disorders which may induce clinical tetany-like symptoms in cows, including milk fever and hypomagnesemic tetany or grass tetany. Clinical cases of tetany are almost exclusively seen in females at or around parturition.

The effects of metabolic diseases involving tetany-like symptoms have been extensively researched in dairy cattle. Several causes of milk fever and mechanisms of action have been identified and methods of treatment and prevention are utilized extensively within the industry. Manipulation of dietary parameters including the dietary cation-anion balance and total calcium, magnesium and phosphorus content of the diet are used to prevent the occurrence of milk fever and other metabolic diseases in dairy cattle (Block, 1984; Horst et al, 1997). In contrast, there is little published research that has been conducted in regard to similar metabolic diseases causing tetany-like symptoms observed in beef cattle. In recent years, the occurrence of tetany-like symptoms in beef cattle herds has become more prevalent in some areas of Saskatchewan (Hanif et al., 1990; Doig, 2002; Tom Schmidt, personal communication). Interest in the possible causes of such an outbreak of the disease leads to discussion of the feed source and quality being fed to the cattle. The feed source of beef cattle is often variable and dependant on feedstuffs that are most readily available at a particular time. Feed supply can be subject to change with weather conditions, location, the type of crops grown and

the price of feed. Because the increased occurrence of tetany-like symptoms in beef cattle seems to be affecting herds located in a similar area within the province, it may be an indication that there is a common factor that is the underlying cause.

The economic implications of metabolic diseases such as milk fever and tetany affect the individual producer as well as the industry as a whole if the problem becomes too widespread. Death loss is a major source of economic impact, but veterinary costs as well as increased labor and feed costs also play a role. When cases of tetany-like symptoms were uncommon and relatively rare, the incidents were likely isolated and unrelated. The economic impact was minimal and there was no large concern in determining the causes. However, in certain locations, the incidence of such problems has been increasing in frequency and numbers to the point where it represents both economic and welfare concerns for producers. There is much interest in discovering if there is an underlying cause that is responsible or partially responsible for this increase.

The purpose of this thesis was to conduct a field study investigating the nature of the observed disease in beef cattle exhibiting tetany-like symptoms. An examination of the possible factors involved in the widespread occurrence of these symptoms in beef cattle during the winter and spring of 2002 will also be conducted. Hopefully, insight into the nature of this disease from a nutritional perspective will be gained from this project, as well as knowledge that will be useful to producers when formulating their wintering rations in order to prevent further cases of the disease and avoid unnecessary economic implications.

2.0 Literature Review

2.1 Metabolic diseases involving tetany

2.1.1 Hypomagnesemic Tetany

2.1.1.1. Symptoms

Hypomagnesemic tetany, also known as grass tetany (kopziekte), grass staggers, winter tetany, lactation tetany and wheat pasture poisoning, is a complex metabolic disturbance characterized by low plasma magnesium (<0.65 mmol/L) and a reduction in the concentration of magnesium in the cerebrospinal fluid (<0.5 mmol/L) (Aiello 1998). Several different names for this disease have been used based on differing metabolic and environmental circumstances, for example, grass tetany refers to animals that exhibit tetany-like symptoms after being turned out on lush pasture while winter tetany refers to animals fed on winter rations that exhibit similar symptoms (Grunes, 1970). Regardless of the cause, the clinical signs are relatively constant in all cases. Hypomagnesemic tetany is a highly fatal disease in all classes of ruminants, but reaches its highest incidence in lactating cows (Radostits et al., 1994). Characteristic symptoms of the disease include decreased milk production, reduced weight gain, depressed appetite, slight nervousness and muscle tremors. In acute cases, hyper excitability, muscular spasms, staggering, and convulsions that eventually lead to death may be observed (National Research Council (NRC) 1996). Very mild disturbances may cause affected animals to begin episodes of bellowing and frenzied movement, and as the symptoms progress, the animal may become recumbent and go into convulsions.

Although hypomagnesemia is the most consistent indicator of the disease, hypocalcemia (<2.00 mmol/L of Ca) is also observed in most clinical tetany cases,

although it is not as severe as seen in parturient paresis or milk fever (Radostits et al. 1994; Kvasnicka and Krysl 1996). Littledike et al. (1983) reported that experimentally induced Mg deficiency is associated with hypocalcemia in cattle. In addition, when Mg in blood plasma is low, low levels of calcium further increase the severity of the symptoms observed in clinical cases of grass tetany (Grunes, 1983).

Kemp (1960) observed that clinical symptoms of hypomagnesemic tetany only occurred when the serum magnesium level was lower that 1.0 mg/100ml. Furthermore, he also noted low serum magnesium levels occurred only when the magnesium content of the forage was less than 0.20%, and that when the forage Mg exceeded this, the serum magnesium level was never lower than 1.5 mg/100ml.

2.1.1.2 Predisposing factors

It has been observed that mature animals are far more susceptible to grass tetany than younger animals because of their inability to mobilize magnesium from their bones in order to meet the requirements of the body (Fontenot, 1979; Kvasnicka and Krysl, 1996; Jefferson et al., 2001). Many sources agree that hypomagnesemic tetany is most common in older milking cows during the first 10 weeks after calving, and the incidence of the disease increases greatly in cows past the third or fourth parity (Grunes et al., 1970). Harris et al. (1983) also reported that the susceptibility to grass tetany increased with the age of the cow.

Research by O'Kelly and Fontenot (1969), estimated that the magnesium requirement of the beef cow doubles from 9.5 to 20.9 g/day (or approximately 0.16% of the ration dry matter) during lactation compared with gestation in order to maintain blood serum magnesium levels of 2.0 mg/100ml. This increased requirement is due mainly to

the increased demand for magnesium in milk production. Milk contains approximately 0.12g Mg/litre and the average beef cow produces 4 litres of milk per day (Mayland and Grunes, 1979). Magnesium lost in milk production must be replaced by absorption from the diet. Therefore, high producing cows past the third or fourth lactation are often more susceptible because of their increased level of milk production. There is also an increased need for magnesium in the last few weeks of gestation when the bone growth of the fetus requires high amounts of magnesium (Littledike and Cox, 1979).

It is well known that low concentrations of magnesium in plants may induce grass tetany in animals (Grunes 1983). Kemp (1960) stated that there was a positive correlation between the magnesium level in herbage and blood serum. Therefore, cows that are fed or grazing low magnesium forages are at higher risk of developing tetany.

Magnesium from the diet is made available to the cow by absorption across the epithelium of the small intestine. Field (1983) suggests that there are two main factors controlling the absorption of magnesium: 1) the concentration of magnesium in the rumen and 2) the efficiency of magnesium transport across the epithelial brush border of the rumen and duodenum. The former is a property of the magnesium content in the diet which is in turn determined by the level of magnesium in the forage and other dietary components. However, hypomagnesemia may not always arise from a simple deficiency of magnesium – the cause of the disease is often complex. Grunes et al. (1970) and Grunes (1983) suggested that the cause of hypomagnesemia may not be so much related to the level of magnesium in the feed as it is to the availability of the magnesium in the dry matter, as well as the amount of milk being produced. Harris et al. (1983) also stated that factors interfering with the absorption of ingested magnesium from the GI tract are

usually more important in predisposing an animal to hypomagnesemic tetany than a low dietary intake of magnesium. Factors affecting the absorption of magnesium will be discussed in further sections of the literature review.

2.1.1.3. *Treatment and prevention.*

Animals showing signs of hypomagnesemic tetany require immediate treatment with combined solutions of calcium and magnesium. Radostits et al. (1994) suggest that a 500ml solution containing 25% calcium borogluconate and 5% magnesium hypophosphite be given intravenously, followed by a subcutaneous injection of 200ml of a 50% solution of magnesium sulfate. There is a certain danger associated with intravenous injection of magnesium salts including respiratory failure, cardiac excitement or depression, and medullary depression, therefore, heart rate and respiration should be monitored closely while the injection is being given (Aeillo, 1998). Follow-up treatment includes the feeding of magnesium-rich supplements such as magnesium oxide to maintain the blood serum magnesium levels high enough to avoid the recurrence of symptoms (Radostits et al. 1994). The interval between the first signs of tetany and death may be as short as 4 to 8 hours, and many animals die before treatment can be given if the condition is not detected early enough (Kvasnicka and Krysl, 1999).

2.1.2. Milk Fever

2.1.2.1. Symptoms

Milk fever, or parturient paresis, is a metabolic disease that develops most commonly at or near parturition and the onset of lactation. The most consistent abnormality observed is an acute hypocalcemia in which the serum calcium falls rapidly from the normal concentration which lies within the range of 2.2-2.6 mmol/L (Allen and

Sansom, 1993). Frequently, hypocalcemia is accompanied by hypophosphatemia and sometimes hypomagnesemia (Underwood, 1981). This loss of calcium is presumably due to the increased requirement for the formation of colostrum. Approximately 2.5 g of calcium are extracted from blood for each kilogram of colostrum produced. This is roughly equal to the total amount of calcium present in the blood at any given time (Horst, 1986). A beef cow that produces 5.0 kg of colostrum uses about 12.5g of calcium. The calcium lost from the plasma pool must be replaced either by increasing intestinal calcium absorption or increasing bone resorption, or both (Horst et al., 1997). In dairy cattle as well as beef cows, the incidence of milk fever appears to increase as the level of average milk production increases.

Characteristic signs of the disease include general muscular weakness and twitching, circulatory collapse, subnormal temperature, increased heart rate, sternal recumbancy, and loss of consciousness. During the early stages of this disease cows show signs of hypersensitivity and excitability, slight ataxia, muscular tremors, and general restlessness – very similar to the signs of hypomagnesemia. The serum calcium levels of all cows' falls somewhat at parturition and the onset of lactation. Hove (1986) reported that the average minimum concentrations of plasma calcium at calving in cows that showed hypocalcemia post calving and those that were normal dropped to 1.2 mmol/L and 2.03 mmol/L, respectively. However, it was noted that in the cows not exhibiting milk fever, the average plasma calcium levels recovered and were maintained above 2.18 mmol/L from 5 to 14 days after calving. In contrast, those cows that developed milk fever showed a second abrupt decrease in plasma calcium to 1.85 mmol/L about one week after calving as well as several smaller subsequent drops 19 to

27 days after calving. Although all cows experience a certain decrease in plasma calcium at calving, it appears that affected animals were less capable of recovering from the drop in calcium and maintaining plasma calcium above the lower normal limit than those that were unaffected. This difference is what seems to cause varying susceptibility of animals to the disease.

2.1.2.2 Predisposing factors

There have been several important predisposing factors identified which seem to increase the risk of milk fever in certain animals. Similar to hypomagnesemic tetany, the incidence of milk fever increases with the age and parity of the cow. It is very rare for parturient paresis to occur in heifers, but by the sixth lactation, as many as 20% of cows will experience the disease (Allen and Sansom, 1993). The effect of age on the incidence of milk fever is twofold. First, as cows get older they gradually lose the ability to mobilize calcium stores from the body when there is a sudden increase in demand for calcium or decreases in the input of calcium. Lactation is a time of high calcium demand, hence, many cases of milk fever are observed near this time.

The second effect of age on the incidence of milk fever is associated with milk production. A cow's milk yield increases with parity, particularly up to the fourth lactation (Allen and Sansom, 1993), therefore the requirement for calcium continues to increase with the age of the animal, and high producing cows are often more susceptible.

Diet has also been identified as a contributing factor to the occurrence of milk fever. Littledike and Cox (1979) noted that overabundant levels of calcium in the diet of a preparturient cow have been known to predispose the animal to milk fever. When there is more calcium supplied in the diet than the body requires, the calcium conservation

mechanisms become relatively inactive. As lactation is initiated and the demand for calcium increases, these mechanisms are activated as the body attempts to increase absorption from the gut and mobilization from bone. However, reduction in the activity of absorption mechanisms due to lack of stimulation can limit the amount of absorptive increase in response to the sudden demand for calcium (Goings et al., 1974). In addition, there is a certain lag period between PTH stimulation and increased mobilization of bone calcium (Goings et al., 1974) which is greater when the system is not adapted, as in cows fed high calcium diets. These mechanisms require several days to become effective once again, and hypocalcemia and hypophosphatemia may occur in the interim (Littledike and Cox, 1979).

2.1.2.3. Treatment and Prevention.

Early diagnosis and treatment of clinical signs of milk fever will allow the best response to treatment and improve chances of recovery. The goal of treatment for milk fever is to restore normal serum calcium levels as soon as possible in order to prevent muscular and nervous damage from occurring. Recommended treatment is an intravenous injection of approximately 500 ml of calcium gluconate (Allen and Sansom, 1993; Aiello, 1998). Calcium is cardio toxic, and therefore this solution should be administered slowly while closely monitoring heart rate and discontinued if bradycardia or dysrhythmias develop. A second dose given subcutaneously is thought to provide additional prolonged release of calcium into the circulation, thus reducing the chances of relapse (Blood et al., 1979).

One of the most effective means to prevent milk fever is to avoid excessive dietary calcium in the prepartum diet (Block, 1984; Horst, 1986). Cows fed a diet low in

calcium prior to calving cannot meet their calcium requirements for maintenance or fetal skeletal development from the diet. As a result, they are in negative calcium balance which causes the stimulation of calcium resorption by activation of bone osteoclasts and renal tubules through the action of parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D_3 [1,25$(OH)_2$ D_3] (Horst et al., 1997). Thus, at the onset of lactation, these calcium homeostatic mechanisms are already active and help to prevent severe declines in plasma calcium concentration.

2.2 Metabolic role of electrolytes

Although imbalances and extreme levels of electrolytes such as sodium, potassium, calcium and magnesium in the body can cause metabolic problems, these particular minerals are essential to many metabolic functions and body processes. The basic metabolic functions, body requirements and sources of these minerals will be reviewed.

2.2.1 Potassium

2.2.1.1 Metabolic Function.

Potassium is the third most abundant mineral in the body and is important for several body functions including osmotic pressure, acid-base and water balance, muscle contraction, nerve impulse transmission and enzymatic reactions. Ninety-eight percent (approx. 140 mEq/L) of the total body potassium is located within cells. Conversely, the concentration of extracellular potassium is fairly low at about 5 mEq/L (NRC, 1996). The large potassium gradient from inside to outside of cells along with the sodium gradient that exists from outside to inside are both important to the development of membrane potential. Through the action of the sodium-potassium pump as well as

potassium-sodium leak channels, the resting membrane potential of nerve cells is established (Guyton and Hall, 2000). An action potential occurs when a rapid change in the membrane potential spreads rapidly along a nerve fiber membrane and produces a response such as muscle contraction. Potassium imbalances may alter the function of the excitable membrane, thus causing problems with nervous function and manifestation of clinical signs of tetany.

2.2.1.2. Body Requirements.

Potassium is the third most abundant mineral element in the body and is required by the cow in the greatest amount of all the mineral cations (NRC, 2001). Storage of this element is limited and therefore, it must be supplied daily in the diet. If more potassium is consumed than can be utilized by the body, the excess is excreted in the urine. Grunes (1983) recommended 0.5% potassium for lactating dairy cows, however, more recent sources list a potassium requirement for lactating dairy cows of 0.9% – 1.0% of the ration dry matter and 0.65% - 0.7% during the dry period (NRC, 2001).

Although potassium requirements for beef cows are not well defined, NRC (1996) suggested that gestating beef cows require 0.5% to 0.7% potassium in their ration. Potassium concentration in milk averages 0.15% and loss by lactating cows is approximately 15g/kg of milk produced (McDowell, 1992). For this reason, lactating animals have higher dietary requirements for potassium – up to an additional 0.13% of dry matter intake, bringing total potassium requirements to between 0.6 and 0.8% during lactation (NRC, 1996).

The direct toxic effects of excess potassium in the body are the direct result of increased levels in the ECF. Hyperkalemia, or high potassium in the blood, is most often

the result of acute renal failure due to prolonged intake of large amounts of potassium or serious acidosis (Tasker, 1980). The primary danger of hyperkalemia is cardiac arrest which may be observed when serum potassium is 7 to 8 mEq/L (Tasker, 1980).

Plasma (extracellular fluid) potassium concentration is tightly regulated due to the fact that fairly small changes can have marked effects on organ function. The normal range of blood potassium levels is 3.9 to 5.8 mmol/L (Puls, 1988), however, potassium concentration in blood is not always a reflection of total body potassium since only a small portion of the total body potassium is found in the extra cellular fluid (French et al., 1999).

2.2.1.3. Sources

Forages are a good source of potassium for ruminants and typically contain between 1% to 4% K (NRC 1996), but this can vary greatly depending on species/variety of forage, maturity, weather conditions, soil type and fertilizer application and moisture conditions. The National Academy of Science (1971) lists the average potassium content of alfalfa hay in early bloom as 1.86%. Two different varieties of alfalfa grown near Outlook, Saskatchewan in the summer of 2002 contained an average potassium content of 1.94% and 2.07, respectively ((D.A.Christensen, unpublished data)). Two varieties of timothy hay were also grown at the same location and had average potassium levels of 1.92% and 1.98%, respectively. Cereal crops cut for silage or greenfeed may also contain 1.40 – 2.57% K depending on the maturity of the crop (NRC, 1996).

Potassium is found in highest concentrations in plant leaves rather than seeds (McDowell, 1992), therefore, cereal greenfeeds and hays will be higher in potassium than grains which are generally low in potassium (<0.5%) (NRC, 1996). Animals fed high-concentrate diets may develop potassium deficiencies as a result. Potassium supplementation is seldom needed if enough forage is fed to supply the level required. Several compounds used in experimental situations as supplemental sources of potassium include potassium bicarbonate (Newton et al., 1972 and Green et al., 1983b), potassium chloride (Bohman et al., 1969), potassium carbonate (Fisher et al., 1994) and potassium sulfate.

2.2.2 Magnesium

2.2.2.1. Metabolic Function.

Magnesium is widely distributed in animal tissues, with approximately 70% of total body magnesium present in the skeleton (Underwood, 1981), 15% in muscle, 15% in soft tissues, and approximately 1% in the extracellular fluid (NRC 1996). Magnesium functions as a co-factor and is responsible for the activation of enzymes required for the metabolism of lipids and carbohydrates (NRC 1996). It is also required for the formation of ATP, the major energy source for all cellular functions. In addition, magnesium ions are involved in the maintenance of electrical potential across nerve and muscle membranes, and thus exert influence on neuromuscular activity (Underwood, 1981). This function is of particular relevance in relation to the development of tetany.

2.2.2.2. Body Requirements.

Normal plasma magnesium concentrations of cattle have been reported to be 2 mg /100 ml (O'Kelly and Fontenot, 1969), 1.7 to 3.3 mg/100ml (Littledike et al., 1983) and

1.8 to 3.5 mg/dl (Puls, 1988), 0.74 to 0.95 mmol/L (Kaneko, 1997) and 0.75 to 1.0 mmol/L (NRC, 2001). Several sources recommend that in order to maintain blood serum levels of magnesium within safe limits, cattle should be fed rations with magnesium concentrations of 0.20% or more during lactation (Grunes et al., 1970; Crawford et al., 1998; Kvasnicka and Krysl, 1999) and 0.10 to 0.13% during gestation (NRC 1996). When expressed as g/day, O'Kelly and Fontenot (1969) recommended 18 to 22g Mg/day for lactating cows. These recommendations may vary depending on the availability of magnesium in the forage (Grunes, 1983), as well as the efficiency of absorption. According to the NRC (1996), the normal efficiency of dietary absorption of magnesium is between 10 and 37%. As with potassium, cows rely on daily absorption of magnesium to avoid deficiencies due to the small reserve in body fluids. This becomes even more crucial during lactation, when the cow's magnesium requirements increase. Similar to calcium, bone metabolism is often insufficient to meet increased magnesium demands of lactation and growth. Figure 2.1 shows the various pathways that magnesium follows within the body after ingestion.

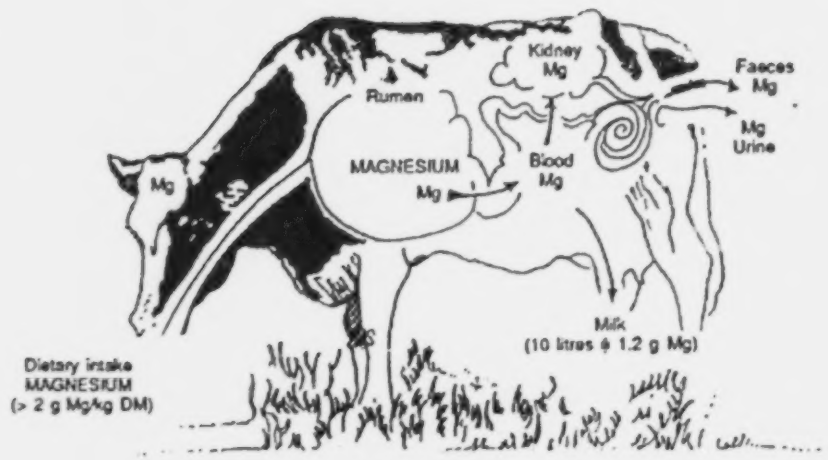

Figure 2.1 Flow and excretion of magnesium in the cow (Elliott, 1999)

2.2.2.3. Sources

Similar to other minerals, the magnesium content of plants varies with species, soil characteristics and maturity. Legumes such as alfalfa and clover are generally richer in magnesium than cereals and grasses. Cereal grains have moderate levels of magnesium, usually containing 0.12 to 0.17% Mg (Saskatchewan Feed Test Laboratories, 1989). According to the National Academy of Sciences (1971), the average magnesium content of alfalfa and clover hay is 0.27 and 0.28%, respectively, however, seasonal variations in the magnesium content of forage is very wide and therefore, this number is subject to significant variation. Two varieties of alfalfa grown at Outlook, Saskatchewan in 2002 had a magnesium content of 0.44% and 0.39%, while two varieties of timothy grown at the same location contained 0.12% and 0.16% magnesium, respectively (D.A.Christensen, unpublished data).

Kemp (1960) reported that the lowest magnesium content of forage occurred in early spring and late autumn. Minson (1990) also observed that 65% of cool-season

forages contain less than 0.20% magnesium, thus there may be a need for magnesium supplementation during these times.

In situations where the available forage is low in magnesium and cattle are susceptible to hypomagnesemia, supplementation of magnesium may be necessary. Magnesium oxide and magnesium sulfate are good sources of magnesium, but are unpalatable and must be combined with ingredients such as concentrates or hay (Aiello, 1998).

2.2.3 Calcium

2.2.3.1. Metabolic Function.

Calcium is the most abundant mineral in the body and functions primarily as a structural component of bones and teeth where 98% of total body calcium is located. The remaining 2% is found in the extracellular fluids and soft tissues where it is involved in several vital functions such as blood clotting, membrane permeability, activation of enzymes, muscle contraction and nerve impulse transmission (NRC 1996). Muscle contraction and nerve impulse transmission are the primary calcium-related processes that are related to the development of tetany symptoms. Calcium ions are an essential part of the excitation-contraction coupling process of muscle contraction. Calcium ions are released from the sarcoplasmic reticulum in response to an action potential traveling along muscle fiber membranes. Calcium binds strongly with troponin, and initiates muscle contraction (Guyton and Hall, 2000).

2.2.3.2. Body requirements.

For lactating dairy cattle, large amounts of calcium are required for milk production, for example, a cow producing 10 L of colostrum may lose as much as 23 g of

calcium in a single milking (Horst et al., 1997). The same is true for beef cows during lactation, but the demand for calcium is not as high. According to the NRC (1996), beef cattle have a maintenance requirement of 16 g/day during the dry period. This increases to 29 g/day in late pregnancy and 33 to 36 g/day during lactation due to the increased demand for calcium for fetal bone formation and milk production, respectively. When calculated as a percentage of the diet, it has been suggested that 0.18 to 0.29% Ca is adequate for lactating cows (Underwood, et al., 1981). Normal plasma Ca concentrations range from 2.43 to 3.10 mmol/L or 9.7 to 12.4 mg/dl (Kaneko et al., 1997). Puls (1988) reports normal calcium levels as 2.0 to 2.74 mmol/L or 8.0 to 11.0 mg/dl. The calcium lost from the plasma pool must be replaced either by intestinal calcium absorption or bone resorption.

Total plasma calcium concentration is controlled by the complex interaction of the calcitropic hormones, parathyroid hormone (PTH) and Vitamin D (1,25-dihydroxyvitamin D_3), both of which are produced in response to hypocalcemia and act to increase the entry of calcium into the plasma calcium pool (Horst et al., 1997). Absorption of calcium occurs primarily in the duodenum and jejunum by both active transport and passive diffusion (McDowell, 1992). Vitamin D is essential for this process and helps to increase the rate of passage across the intestinal epithelium (Guyton and Hall, 2000). Bone is the major source of calcium during periods of low intake. PTH is released from the parathyroid glands in response to low blood calcium levels, and acts to increase the resorption of calcium from bone and incorporate it into the calcium pool where it is then available for metabolic functions.

2.2.3.3. Sources.

The calcium content of forages is affected by species, age and stage of maturity. Legume forages in general are a good source of calcium. The National Academy of Sciences (1971) lists the average calcium content of alfalfa in early bloom as 1.26%. Alfalfa grown near Outlook contained an average of 1.97% calcium ((D.A.Christensen, unpublished data)). In contrast, grass and cereal forages and grains are consistently low in calcium, for example, oat and barley hay contains 0.38 to 0.47% Ca (Saskatchewan Feed Test Laboratories, unpublished data). Timothy grass (*Phleum pratense*) grown at Outlook had an average calcium content ranging between 0.22 and 0.36%. Cereal grains are even lower in calcium and contain an average of 0.08% Ca (Saskatchewan Feed Test Laboratories, unpublished data). Therefore, high grain diets often require supplemental calcium which can be supplied by several sources, including calcium carbonate, ground limestone, and bone meal. Other products such as dicalcium phosphate and monocalcium phosphate provide phosphate as well as calcium and may be more desirable, depending on the situation.

2.2.4 Phosphorus

2.2.4.1. Metabolic Function

Phosphorus is most commonly discussed in conjunction with calcium because the function and uptake of these minerals by the body are very closely linked. Of the many roles that phosphorus plays in the body, its primary function is in the structure of bones and teeth where 80% of phosphorus in the body is located (NRC 1996). The remainder is distributed in the soft tissues where it plays a role in several metabolic functions. Phosphorus is involved in cellular energy transfer via the ADP - ATP system, and is a

component of DNA and RNA. Phospholipids are a major constituent of membranes in the body and phosphorus is also important for lipid metabolism. Phosphorus is found in large quantities in ruminant saliva (8 mmol/L) (Cook, 1995). In ruminants, the alimentary tract rather than the kidneys is the most important route for phosphate excretion (Care et al., 1979). Phosphate is usually absorbed readily, but Vitamin D enhances the movement across the gastrointestinal epithelium (Guyton and Hall, 2000).

2.2.4.2. Body Requirements

Phosphorous requirements vary depending on the physiological and metabolic state of the animal. Specifically, dry cows need between 12 and 22 g/day depending on body weight and lactating animals with an average milk production of approximately 5.0 kg/day require between 18 and 27 g/day (Simons and Hand, 1993).

As previously mentioned, calcium concentration is regulated precisely via the interaction of calcitrophic hormones. In contrast, the concentration of plasma phosphorus is controlled less stringently, even though the same two hormones, PTH and Vitamin D3, are responsible for its regulation. The normal level of phosphorus in blood serum ranges from 1.18 to 2.10 mmol/L or 5.6 to 6.5 mg/dl (Kaneko, 1997).

2.2.4.3. Sources.

Phosphorus is often supplemented in conjunction with calcium in the form of dicalcium phosphate, bone meal and defluorinated phosphate. Supplementation may be required in arid and semiarid areas where the soil is deficient in phosphorus. In addition,

mature forages and crop residues generally contain low levels of phosphorus (Simons and Hand, 1993). Unlike calcium, cereal grains provide moderate to high levels of phosphorus to the diet. Barley and oat grains typically contain between 0.35 and 0.41% phosphorus (NRC, 1996)

2.3 Interaction of electrolytes

Over the years it has been observed that not only the concentration of a certain mineral element in the diet is important, but the relative amounts of several minerals in relation to each other have also been identified as being of great importance with regard to animal nutrition. Various electrolytes may affect the metabolism of other electrolytes within the body, including absorption and utilization (Figure 2.2). With respect to the subject of tetany-like diseases and their metabolic causes, there are three such relationships between electrolytes that are of interest: the calcium-phosphorus ratio, the tetany ratio and the dietary cation-anion balance (DCAB).

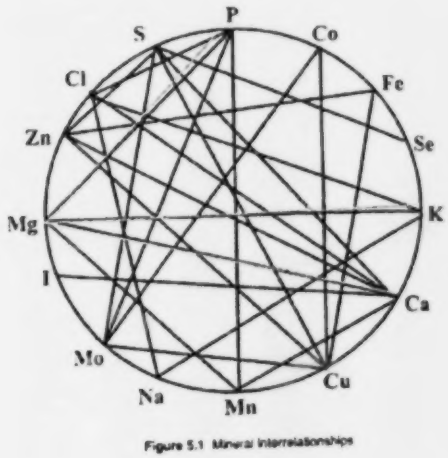

Figure 2.2 Mineral Interrelationships (Leeson and Summers, 2001)

2.3.1 Calcium:Phosphorus Ratio

As previously mentioned, calcium and phosphorus homeostasis are closely linked. The function of these two minerals is intertwined and they often share the same control mechanisms. Several studies on the effects of the absolute and relative amounts of calcium and phosphorus in the diet of parturient cows have been conducted. Tanaka and DeLuca (1973) reported that high phosphorus intake interferes with vitamin D metabolism, thus affecting its positive influence on calcium absorption and making it a possible cause of hypocalcemia. It is also recognized that low prepartum calcium diets tend to be beneficial, because they stimulate the synthesis of Vitamin D_3 [1, $25(OH)_2D_3$], which in turn increases the rates of calcium mobilization and absorption from bone at parturition (Allen and Sansom, 1993). If high calcium diets are fed, the entire calcium requirement can be absorbed from the diet and the Ca mobilization system becomes relatively inactive. When a sudden demand for Ca occurs, such as at parturition, it takes several days for the Vitamin D mobilization system to begin functioning at normal levels again, and in the meantime, hypocalcemia can occur.

In addition to individual levels, the relative amounts of calcium and phosphorus in the diet is also important. Several studies (Dowe et al., 1957; Wise et al., 1963; Ricketts et al., 1970; Alfaro et al., 1988) reviewed by NRC (1996) have shown that dietary Ca:P ratios of between 1:5 and 7:1 result in similar performance, provided that phosphorus intake is adequate. However, these recommendations may not relate specifically to cows in late gestation and early lactation when too much or too little calcium can be a problem. A general consensus by several researchers seems to be that a Ca:P ratio of 2.2 to 2.3:1 is the optimum level for improving absorption of both calcium and phosphorus and thus

preventing or reducing the incidence of parturient paresis in dairy cattle (Manston, 1967; Kendall et al., 1970; Gardner and Park, 1971). Kendall et al. (1970) conducted an experiment comparing the effects of diets with Ca:P ratios of 4:1, 2.3:1 and 1:1. Their results indicated that cows fed diets containing ratios of 4:1 and 1:1 exhibited a higher incidence of milk fever in comparison to cows fed the diet with a 2.3:1 ratio. However, some researchers have observed milk fever even when the Ca:P ratio was adjusted to the proposed optimum (Beitz et al., 1974). They suggested that factors other than the Ca:P ratio must play a role in the development of parturient paresis. The NRC (1996) suggests a Ca:P ratio of approximately 1.5 for beef cows.

Horst et al. (1997) related the view that the total amount of dietary calcium in the prepartum diet was more important than the dietary ratio of Ca:P and the suggestion that limiting calcium intake to less than 100 g per day may be more effective in the prevention of milk fever. There is little information specifically related to beef cattle on this subject, however, the optimum calcium intake can be assumed to be similar to that recommended for dairy cattle.

2.3.2 Dietary Cation-Anion Balance

A more recent approach to reducing and preventing metabolic diseases through dietary manipulation is the alteration of the ionic balance of the diet. Horst et al. (1997) reviewed studies which discovered that feeding inorganic acids to cow's prepartum significantly reduced the incidence of milk fever. They proposed that the occurrence of milk fever depended on the relative amounts of cations (Na+ and K+) to anions (Cl- and SO_4^{2-}) in the diet. This concept is referred to as the dietary cation-anion balance (DCAB) and is most commonly expressed as:

$$DCAB\ (mEq) = (Na + K) - (Cl + S)\ \text{(Byers, 1993; Oetzel, 1993)}$$

Calculation of the DCAB of a diet requires the use of equivalent weights of the electrolytes because acid-base balance is affected by electrical charge rather than mass (Oetzel, 1993). One equivalent weight is equal to the molecular weight, or the weight of one mole of atoms of the element, divided by the valence of the ion (i.e., strength of the electrical charge). Therefore, one equivalent weight of magnesium (mol. wt. = 24.3g) is equal to 12.2 g because magnesium is a divalent cation (Table 2.1). On the other hand, the equivalent weight of potassium is equal to the molecular weight because this molecule has only a single charge.

Table 2.1 Molecular weights, equivalent weights and conversions from percentages to milliequivalents per kilogram of anions and cations used in the calculation of DCAB and tetany ratio. (Oetzel, 1993)

Element	*Molecular weight (g)*	*Valence*	*Equivalent weight (g)*	*To Convert from Percentages to Milliequivalent per Kilogram, Multiply by:*
Sodium	23.0	1	23	434.98
Potassium	39.1	1	39.1	255.74
Calcium	40.1	2	20.1	282.06
Magnesium	24.3	2	12.2	623.75
Chlorine	35.5	1	35.5	499.00
Phosphorus	31.0	1.8[a]	10.3	581.14

[a]The valence of phosphorus is 1.8, based on the normal distribution of monohydrogen and dihydrogen forms of phosphorus in the body.

The DCAB is involved with acid-base metabolism. The body strives to maintain equilibrium between acidic and basic components, that is, to ensure that the sum of the positive charges in solution equal the sum of the negative charges. The principle of electrical neutrality is the underlying principle of DCAB. When the DCAB value of a

diet is negative, that is, the sum of the anions is greater than the sum of the cations, there will be a slight decrease in blood pH (metabolic acidosis). This increase in acidity will elicit a basic response from the body as it strives to return the system to equilibrium by mobilizing cations such as calcium to provide buffering capacity (Byers, 1993). In order to buffer the excess anions, cations from body reserves are mobilized. Horst et al. (1997) suggested that mild metabolic acidosis induced by the addition of Cl- or SO_4^{2-} to the diet increased bone resorption by osteoclasts and synthesis of 1,25 $(OH)_2D_3$, thus increasing blood calcium levels.

Research in this area has indicated that a diet with a negative dietary cation-anion balance is beneficial in prevention of milk fever in cattle (Block, 1984; LeClerc and Block, 1989; Oetzel, 1993). Block (1984) reported that cows consuming an anionic diet were able to maintain calcium and phosphorus levels in blood plasma through parturition, whereas cows consuming the cationic diet showed a decline in these minerals around calving. The incidence of milk fever for cows offered the anion diet was zero, compared to 47.4% incidence in cows fed the cationic diet. Later studies by LeClerc and Block (1989) and Kim et al. (1997) showed similar results.

Leclerc and Block (1989) and Block (1984) indicate that the critical dietary cation-anion balance for the prepartum dairy cow is between +62 and –128 mEq/kg DM to prevent milk fever. Byers (1993) suggests at least –15 mEq/100g DM. A DCAB of -100 meq/kg DM was also recommended by Horst et al. (1997). Recommendations for beef cattle are slightly different and some sources suggest that a diet with DCAB below +150 to +200 is sufficient to prevent milk fever (Alberta Agriculture, 1999).

Although most emphasis has been put on the addition of anionic salts to decrease the acid-base balance, DCAB is also affected by the cations in the diet. Goff and Horst (1997) provided evidence that dairy cows fed a diet low in potassium or sodium have lower incidence of milk fever than those on diets high in potassium or sodium. They reported that addition of strong cations to the prepartum diet increased blood and urine pH, and suggested that bone resorption of calcium was inhibited in cows fed high potassium or high sodium diets as a result of metabolic alkalosis. They proposed that high levels of potassium and sodium, and not low calcium, was the major underlying factor causing milk fever. They reported that increasing the dietary potassium to 2.1 or 3.1% increased the incidence of milk fever to 10 of 20 cows and 11 of 23 cows, respectively, and increasing dietary sodium to 1.3% induced milk fever in 5 of 8 cows. This data suggests that the underlying cause of milk fever in dairy cows is metabolic alkalosis.

2.3.3 Tetany Ratio

A third property of dietary rations that involves electrolyte balance is known as the tetany ratio, and is primarily involved in the development of grass tetany. Kemp and 't Hart (1957) conducted preliminary research on various factors affecting the incidence of grass tetany in cows. They carried out a large survey and concluded that certain cation-anion relationships were important to the development of grass tetany. One of their observations was that the ratio of potassium to the sum of calcium and magnesium in the forage was significantly correlated to the incidence of tetany in grazing cows. This so called 'tetany ratio' is expressed as K/(Ca+Mg) in milliequivalents per kg of dry matter (Kemp and 't Hart, 1957). From their survey, the results indicated that when the

ratio of K/(Ca+Mg) in the forage was less than 2.2, there were very few cases of tetany (0.77% of 4658 animals), however, with a value greater than 2.2, the frequency of tetany increased (6.66% of 1908 animals). Research by Butler (1963) found a very positive correlation between the K/(Ca+Mg) ratio and the incidence of grass tetany, thus supporting the conclusions of Kemp and 't Hart (1957). It was found that when potassium concentrations are high and magnesium concentrations are low in pasture forage, the risk of tetany was increased. Thus, from the equation, it is obvious that three factors can cause the tetany ratio to increase: increased potassium, decreased calcium or decreased magnesium.

The tetany ratio of the feed can have an effect on the level of blood serum electrolytes. Bohman et al. (1983) observed the incidence of hypocalcemia in cattle affected with grass tetany. As previously mentioned, cows that develop clinical signs of grass or winter tetany often exhibit both hypomagnesemia and hypocalcemia.

Kemp and 't Hart (1957) also noted that pastures where tetany cases were observed had appreciably higher amounts of potassium to the other cations as compared to pastures without tetany. Investigation into the effects of temperature indicated that increased uptake of potassium by plants followed a rise in temperature. Further work on the subject, related by Grunes et al. (1970), involved monitoring the magnesium and calcium concentrations of forages at different temperature conditions. It was found that magnesium and calcium concentrations were much higher for plants grown at 20°C than at 10°C, thus causing the K/(Ca+Mg) ratio to be higher at lower temperatures. Grunes et al. (1970) also related that the tetany ratio was observed to be higher in plants grown at 10°C than 20°C.

2.3.4 Factors affecting mineral absorption

Although certain minerals may be supplied in the diet in sufficient quantities, the actual amount that is available to the body for metabolic processes depends on the availability of that particular mineral. This is largely based on absorption. For example, assuming 37% absorption of Mg, which is considered normal for cattle, a cow must consume 57g of magnesium in the diet in order for enough to be absorbed into the blood to meet the daily requirement of 21g.

The electrolyte balance and interaction between them plays an important role in the efficiency of absorption across the epithelium in the gastrointestinal tract and the ultimate quantity that is made available to the body. Several of these interactions have been identified.

2.3.4.1. Interference with magnesium absorption

Availability and absorption of calcium or magnesium can be influenced by other dietary factors (Kvasnicka and Krysl, 1999). High levels of organic acids in forages may complex with magnesium and reduce its bioavailability to the ruminant animal (Mayland and Grunes, 1979). Other research has indicated that high dietary intake of nitrogen, lipids, potassium and trans-aconitic acid have been associated with tetany, even when adequate levels of magnesium and/or calcium are supplied. The detailed investigation into all of these is beyond the scope of this paper, however, the effects of potassium with respect to the incidence of hypomagnesemic tetany will be investigated.

High potassium intake, equivalent to that experienced by ruminants grazing spring herbage, decreases the absorption of magnesium from the gut and, when associated with a low magnesium intake, may induce hypomagnesemia and grass tetany

(Field, 1983). Many other sources have also noted that high forage potassium seems to be a major factor associated with the occurrence of grass tetany in beef cows (Newton et al., 1972; Green et al., 1983b; Kvasnicka and Krysl, 1999).

Early experiments by Kemp (1960) showed a significant negative correlation between the serum magnesium levels and the percentage of potassium in the herbage. Newton et al. (1972) conducted an experiment to determine the effect of high potassium rations on the magnesium absorption in sheep. Supplemental potassium bicarbonate was added to the diet of lambs and the results indicated that the animals fed high potassium rations tended to have lower concentrations of blood serum magnesium. In a similar study, Green et al. (1983b) found that magnesium absorption decreased linearly with increasing level of dietary potassium. High levels of potassium depressed magnesium absorption by 20% in the stomach of lambs, but did not affect magnesium absorption in the small and large intestine.

The rumen is the primary site of magnesium absorption (Fonetnot, 1979; Green et al. 1983a), which occurs via a sodium-linked active transport process (NRC 2001). It is not clearly understood how potassium interferes with magnesium absorption, but it likely acts through the magnesium transport mechanism. Martens and Rayssiguier (1980) noted that absorption of magnesium was an active sodium-linked process mediated by Na-K ATPase, and high potassium diets interfere with ruminal absorption of magnesium by acting as a competitive inhibitor of magnesium at the receptor site. Such inhibition can be a major cause of hypomagnesemia.

Despite the uncertainty about the actual mechanism of action, high levels of potassium have proven to be a major factor in the inhibition of magnesium absorption and thus linked to the cause of hypomagnesemia and tetany.

Mg absorption is enhanced by high dietary levels of phosphorus. Low calcium causes the concentration of magnesium in the CSF to fall more rapidly as magnesium in the blood decreases, therefore low calcium and phosphorus may contribute to hypomagnesemia (Elliott, 1999). Passage of magnesium across the gut wall is enhanced by a high Nark ratio and inhibited by a high ammonia concentration (Field, 1983).

2.3.4.2. Interference with calcium absorption

Horst (1986) reported that low dietary phosphorus as well as dietary fat and large amounts of magnesium fluoride have been implicated in reduced availability of calcium for absorption. A decrease in calcium digestibility has also been cited as a consequence of phosphorus deficiency in ruminants. Care et al. (1979) reviewed several sources which concluded that calcium absorption in sheep is reduced by dietary phosphorus deficiency.

Bohman et al. (1969) lowered plasma magnesium by adding supplemental potassium to the diet of cattle, however, there was no measurable effect on plasma calcium. However, a study by Goff and Horst (1997) showed that high dietary potassium might interfere with calcium absorption in the rumen and consequently increase the risk of milk fever. The primary contribution of high potassium to increase the risk of milk

fever is by increasing the DCAB, causing metabolic alkalosis and reducing the responsiveness of bone and kidney to PTH (Goff and Horst, 1997).

2.4 Concentrations of Major Minerals in Forages

Beef cattle in Saskatchewan are fed a variety of legume and cereal forages. The main forage in the diet may change from year to year and from farm to farm depending on factors such as cost, availability of feed, storage options and other economic considerations. This may have a significant impact on the possible occurrence of metabolic diseases due to the fact that different forages can vary significantly in their mineral composition.

Cereal crops such as wheat, oats and barley have intrinsically lower concentrations of magnesium and calcium than legume forages such as alfalfa and clover (Grunes et al., 1970; Elliott, 1999). Cases of hypomagnesemic tetany are more commonly seen when cattle are grazing or fed dominantly grass or cereal crops rather than legume forages (Grunes et al, 1970).

2.4.1 Characteristics of Major Forages

2.4.1.1 Legumes

Plants species vary widely in concentrations of magnesium, calcium and potassium, however, legumes and herbs generally have higher concentrations of magnesium and calcium than do grasses and cereals (Grunes et al., 1970). The average magnesium and calcium concentration of alfalfa and clover hay is 0.27, 0.26 and 1.26 and 1.08%, respectively (National Academy of Sciences, 1971), which contributes to the characteristically low K/(Ca+Mg) ratio observed in many legume forages. Because of its

mineral properties, some sources recommend the addition of legume forages to the diet of cattle fed primarily cereal forages or cattle that are susceptible to grass tetany (Radostits et al., 1994).

2.4.1.2 Cereals/Grasses

Grass tetany has been observed in ruminants grazing perennial grasses such as orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense* L.), crested wheatgrass (*Agropyron desertorum* and *Agropyron cristatum*) and several rygrasses (*Lolium* spp.) (Grunes et al., 1970). The disease is also commonly observed in cattle grazing wheat (*Triticum aestivum*), rye (*Secale cereale*), oats (*Avena sativa*) and barley (*Hordeum vulgare*). Mayland et al. (1976) estimated the tetany hazard of several cereals used as forages and found that the incidence of grass tetany was: wheat > oat = barley > rye.

Typically, wheat, oat and barley hays contain 0.12, 0.22 and 0.25% calcium, respectively. The average magnesium content of cereal grains grown in Saskatchewan was reported as 0.12 to 0.17 % (Saskatchewan Feed Test Laboratories, 1989). Wheat, oats and barley cut for hay have average magnesium contents of 0.12, 0.02 and 0.19%, respectively, which is relatively low in comparison to legumes such as alfalfa which contains an average of 0.35 % magnesium (NRC, 1996). This low magnesium content is often coupled with high potassium, thus increasing the K/(Ca+Mg) ratio and the risk of causing tetany symptoms in cattle.

2.4.2 Plant Uptake of Potassium

Hypomagnesemic tetany, commonly known as grass tetany, is often observed a short time after animals are let out to graze lush spring pasture consisting of grasses

(perennial ryegrass, crested wheatgrass, orchardgrass) and cereal forage (wheat and oats). Several sources suggest that the cause for this is due to a variety of factors including cool, wet weather, low soil Mg, species of the herbage, and maturity of the plant.

2.4.2.1. Fertilizer/Manure

Forages with a high potassium and low magnesium concentration pose a risk for causing hypomagnesemic tetany in beef cattle. There has been increasing concern in recent years, as rising potassium concentration in forages grown for cattle feed have been noted, especially in areas associated with intensive livestock industries (Fisher et al., 1994). Potassium fertilizers have been widely used to improve crop yields, however, they also cause a significant increase in the potassium uptake by forages. Kemp (1960) found that top-dressing of pasture with potash led to a substantial increase in potassium and chloride in the herbage as well as a reduction in magnesium and calcium. He also reported that nitrogen fertilization has a similar effect, increasing potassium uptake by plants.

Another study conducted by Grunes et al. (1992) looked at how fertilization with two different levels of KNO_3 affected the mineral and organic acid content of three cool season grasses (ryegrass, crested wheatgrass and bromegrass). Their findings indicated that potassium fertilization significantly increased the potassium concentrations in the shoots of all species and significantly decreased the concentration of magnesium and calcium in the same plants. There was also a dramatic increase in the organic acid (aconitic, citric and malic) concentration of the forages in response to potassium fertilization. This has significant implications for grazing animals. Grunes et al. (1992) reviewed that trans-aconitate in forage is converted to tricarballylate in the rumen.

Tricarballylate, when absorbed into the blood, can complex with calcium and magnesium, thus decreasing their bioavailability. Another finding by Grunes et al. (1992) was that cation-anion balance of the forage was significantly increased by fertilization with KNO_3.

Application of animal manures to fields where forages are grown for cattle feed has also been implicated in causing higher concentration of potassium in the plants. Ito and Miyazawa (1984) conducted a 16 year study on the effect of long-term application of manure to the yield and nutrient status of forage crops in Japan. Their results indicated that heavy manure application causes an increase in the nitrate and potassium concentration of forage crops and accordingly, increases the risk of grass tetany.

2.4.2.2 Temperature

Grass tetany symptoms occur most frequently in cattle during cool, wet springs in pastures where cattle are grazing rapidly growing grass or small grain forages following a rise in environmental temperature (Grunes et al., 1970). Kemp and 't Hart (1957) reported an increased incidence of hypomagnesemia about 5 days after a rise in temperature to 14 ^{o}C, following cold, wet periods. Cool, wet weather has also been shown to affect the concentration of magnesium in ryegrass. Cheney and Robinson (1985) found that the magnesium content of ryegrass forages was lower in cool weather. A similar observation was noted by Grunes et al. (1970) who reported that a study of crested wheatgrass found that magnesium and calcium concentrations were much higher for plants grown at 20^{o}C than at 10^{o}C. The typical characteristics of forages known to cause grass tetany have been fairly well documented (Grunes et al., 1970; Fontenot,

1979; Cherney and Robinson, 1985). It may be reasonably assumed that when these same forages are cut for hay and fed over the winter months, grass tetany symptoms may develop in the animals consuming the forage. This particular type of the disease is known as winter tetany.

2.4.2.3 Forage Maturity

The age and maturity of the forage has also been identified as a factor influencing the mineral composition of forages. Seasonal variation in forage composition is known to occur and young, immature plants growing in early spring generally have both lower Mg and higher K levels than more mature forages later in the growing season. Time of K uptake varies with different plants, however, plants generally absorb the majority of their K at an earlier growth stage than nitrogen and phosphorus. Some sources suggest that the availability of Mg is lower in young plants and increases as the forage matures (Underwood, 1981; Kvasnicka and Krysl, 1996).

2.4.2.4 Soil Characteristics

Soil moisture levels also influence the electrolyte levels in forage crops. Data from Karlen et al. (1980) indicated that at higher moisture levels, concentrations of potassium were higher and concentrations of calcium and magnesium were lower, consequently increasing the K/(Ca+Mg) ratio. The largest increases in the tetany ratio were observed in samplings taken from plants shortly after emergence, and declined as the plants matured. Low soil moisture tends to impede the diffusion of potassium into plant roots (Prasad et al., 2000). However, excessive moisture may cause leaching of soluble minerals from the soil, thus making them unavailable for plant use.

The mineral levels in the soil also have a direct effect on the composition of plants. The majority of plant minerals such as potassium are absorbed by diffusion and mass flow into the roots. The amount of potassium that can diffuse is directly proportional to the intensity of potassium in the soil solution (Tisdale et al., 1985).

Mineral concentration in forages is also dependent on soil type. Soils are developed from parent rock, therefore there is a wide range of possible mineral concentrations in soils depending on the type of parent material from which it developed. In general, soils developed from acidic igneous rocks are generally low in magnesium, while high levels of magnesium are found in soils derived from more basic rocks (Grunes et al., 1970). Saskatchewan is home to one of the world's largest high-grade potash deposits (Tisdale, 1985), and therefore, many soils throughout the province are naturally high in potassium. It is also possible that the practice of continuous cropping along with applications of potassium and non-magnesium fertilizers may contribute to magnesium deficiencies in some soils.

2.5 Conclusion

Metabolic diseases involving tetany within the cow herd represent a significant economic cost to the producer through death loss, increased labor and veterinary fees. There have been several dietary factors identified that may contribute to the occurrence of hypomagnesemic tetany and milk fever. With proper management, these nutritional risk factors can be reduced or eliminated, thus decreasing the risk of clinical symptoms of tetany in the cow herd.

From the review of literature, it is apparent that the causes for metabolic diseases causing tetany-like symptoms in cattle are varied and complex, but there does seem to be

a significant connection to nutrition and metabolic stage (late gestation and lactation). During the winter of 2001-2002, several factors contributed to the widespread occurrence of tetany-like symptoms in numerous beef cattle herds in west-central Saskatchewan. This incidence of tetany/milk fever symptoms in beef cows presented the opportunity to carry out a case study whose objective was to evaluate the blood serum characteristics and nutritional status of these cows when symptoms were observed. A further objective was to examine the specific dietary components that may have contributed to the occurrence of the observed disease, and to use this dietary information to evaluate how the nutritional management of cows in late gestation and early lactation can be modified in order to prevent or reduce the risk of cows developing tetany-like symptoms.

3.0 Case Study of Beef Cows Affected with Tetany-like Symptoms in Five Producer Herds in West-Central Saskatchewan

3.1 Introduction

Milk fever, or parturient paresis, is a metabolic disease that develops most commonly in high producing, mature dairy cows at or near parturition. This disease is primarily associated with low serum calcium concentrations causing various neuromuscular symptoms including tetany, lateral recumbency, coma and death (Horst et al. 1997). Plasma levels of phosphorus are often low as well. Milk fever most often occurs within 48 hours of parturition, but may also occur several weeks before or after calving (Radostits et al., 1994). The onset of lactation around the time of parturition results in a sudden demand for calcium, and often leads to a deficiency in the blood if the cow is unable to mobilize sufficient quantities of calcium into the calcium pool to meet demands. It has also been reported that pregnant beef cattle can develop hypocalcemia during the winter when fed low quality roughage (Janzen, 1976).

Hypomagnesemic tetany describes a variety of metabolic conditions occurring in ruminant animals and particularly cattle which are generally characterized by convulsions and paralysis. Several known forms of this disease include grass tetany (kopziekte), lactation tetany, grass staggers, and wheat pasture poisoning (Grunes et al. 1970, Littledike et al. 1983). The most consistent sign of grass tetany is hypomagnesemia and this appears to be the distinguishing feature of the disease (Littledike et al. 1983). Mature, lactating cows are more susceptible to hypomagnesemia because they are unable to mobilize calcium and magnesium from their bones during times of high demand relative to younger animals (Fontenot, 1979). Although it is most often associated with the

grazing of lush spring pasture, a type of hypomagnesemia known as 'winter tetany' may also occur and has been reported in beef cattle fed winter rations (Grunes et al., 1970). Kemp (1960) reported a significant negative correlation between herbage potassium and serum magnesium concentration. This has led to speculation about the effects of high levels of potassium in forage fed to cattle being a possible cause of hypomagnesemia. Without treatment, mortality among clinical cases of grass tetany is fairly high and thus represents a possible economical loss to beef producers.

During the winter of 2001/2002, Livestock Agrologists and Veterinary Practitioners in the area surrounding North Battleford, SK noticed an unusual increase in the number of beef producers that were experiencing problems with 'downer' cows. Over 50 different herds in the area experienced problems. This incidence was significantly more than observed in previous years. In some herds, there were several cows affected within the same time period. Most of these animals were in the later stages of pregnancy (2 to 3 weeks prior to calving) or shortly after calving, and showed clinical signs of milk fever and/or hypomagnesemic tetany. Some cows showed classical signs of milk fever including subnormal temperature, increased heart rate, depression, and sternal recumbancy. Other cases were unusual and occurred before calving. Classical milk fever cases most commonly occur about the time of parturition. Most pre-partum cases occur in the last few days of pregnancy and only rare cases occur several weeks before calving (Blood et al., 1979).

One of the major differences between the cases in 2002 and those observed in previous years was that the onset of symptoms was quicker and the progression of deterioration much faster (Tom Schmidt, personal communication). In these 'fast crash'

cases, the symptoms, which in most cases were observed pre-calving, were not necessarily those of a classical milk fever and included increased muscle tone and labored breathing or grunting.

Most cases were successfully treated with intravenous solutions containing calcium, magnesium and phosphorus. These included solutions such as Cal Mag Phos (19.78 mg/mL calcium borogluconate, 150 mg/mL dextrose, 45 mg/mL magnesium chloride, 10 mg/mL phosphorus, 27.5 mg/mL sodium hypophosphite). Another unusual aspect of the cases in 2002 was the fact that larger doses of these solutions were required for treatment of affected cows. Normally, treatment with two 500 mL bottles of a calcium solution is sufficient for a cow with milk fever (Blood et al., 1979). However, several of the affected cows were treated with 5 to 6 bottles before any improvement was observed. The treatment regime consisted of two or three 500mL bottles of Cal Mag Phos by intravenous injection, followed by subcutaneous injection of two or three 500mL bottles of a calcium solution such as 23% calcium borogluconate or Cal-Dextro (containing 16.84 mg Ca, 3.84 mg Mg, 9.8 mg P and 165 mg dextrose) a few hours later or the next day. In some cases when the cows were down for longer periods of time, treatment with an intravenous solution of 50% dextrose was administered as well. Certain cows that went down quickly were also given products such as Peptonic™ or Rumex™ to stimulate rumen function. In general, the earlier the treatment was given, the better was the response to that treatment and the recovery prognosis.

As recommended by a livestock specialist, supplemental magnesium and calcium was added to the feed by some producers in order to prevent further problems within the herd. Calcium, in the form of limestone, was supplied at a rate of 3 oz per head per day.

BayMag™, containing 57% magnesium in the form of magnesium oxide, was recommended at a rate of 1 to 1.5 oz per head per day (Bryan Doig, personal communication). Supplementation seemed to be effective, as there were no problems observed in the herds after adding the limestone and BayMag to the diet.

The number of affected cows in the spring of 2002 – especially several cases occurring within the same herd – was unusual. Nutrition was identified as one of the possible reasons for the 'outbreak' of tetany cases. One common factor that linked herds experiencing problems was the presence of cereal greenfeeds in the dry cow rations. Dry conditions combined with the low yield of alfalfa crops during the summer of 2001 led to an increase in the amount of cereal (oat and barley) crops cut for greenfeed as a replacement for hay. Feed tests in Saskatchewan for cereals grown for forage in 2001 indicate potassium levels as high as 4.2% on a dry matter basis (Doig, 2002). Due to these increased levels of potassium reported in several crops, there was some speculation that the high amount of greenfeed being fed to cows may have been partially responsible for some of the mineral imbalances in the diet such as a high tetany ratio or high dietary cation-anion balance (DCAB).

The tetany ratio is a characteristic of the feed and is expressed as K/(Ca+Mg) in milliequivalents per kg of dry matter (Kemp and 't Hart, 1957). This ratio has been identified as one of the factors primarily involved in the development of grass tetany. High concentrations of potassium or low concentration of calcium and/or magnesium contribute to an increase in the tetany ratio. High potassium intake decreases the absorption of magnesium from the gut and, when associated with low magnesium intake, will induce hypomagnesemia and tetany (Field, 1983). Because a high tetany ratio

implies either increased potassium or decreased calcium or magnesium, it also represents an increased risk of causing hypomagnesemia in cattle. Research has shown that a tetany ratio greater that 2.2 represents a higher risk of causing tetany (Kemp and 't Hart, 1957; Butler, 1963).

Dietary cation-anion balance (DCAB) refers to the proportions of specific fixed ions in the diet. DCAB is most commonly expressed as (Na + K) – (Cl + S) in milliequivalents per kilogram of dry matter (Byers, 1993; Oetzel, 1993). Research has indicated that a diet with negative dietary cation-anion balance is beneficial in prevention of milk fever in dairy cattle (Block, 1984; LeClerc and Block, 1989; Oetzel, 1993). This is accomplished through the principals of acid-base metabolism. A diet with a negative DCAB value will produce a slight decrease in blood pH, causing metabolic acidosis. This increase in acidity will elicit a basic response from the body as it strives to return the system to equilibrium by mobilizing cations such as calcium to provide buffering capacity (Byers, 1993). This will cause an increase in blood calcium levels and ultimately prevent severe hypocalcemia at parturition. At present there are no formal DCAB recommendations for beef cattle, but some sources suggest that a diet with a DCAB below +150 to +200 is sufficient to prevent milk fever (Alberta Agriculture, 1999).

High levels of potassium in the diet will increase both the tetany ratio and the DCAB which will negatively affect the metabolism of cows and may lead to higher incidence of tetany or milk fever.

This project involved conducting a field study of five beef cattle herds located in the North Battleford area in which at least one cow had been treated for tetany-like

symptoms. The objectives were to investigate the nature of the disease and to determine if the increased incidence of tetany-like symptoms were correlated with nutritional factors, particularly high potassium in the ration.

3.1 Materials and Methods

3.2.1 Data Collection

With the cooperation of five cattle producers in the North Battleford area, blood samples were taken from 'down' cows by the veterinarian at the time of treatment. The affected animals were commercial beef cows (Charolais, Simmental and Hereford cross) 4 years of age and older. Some were affected a few weeks before parturition and some after. Blood samples were also taken from 5 to 10 unaffected animals in each herd. These consisted of individuals of various age and metabolic condition, including yearling and two-year-old heifers, mature cows in late gestation and mature lactating cows.

Routine serum biochemistry panel analyses were run on blood serum samples collected from the five herds by the Prairie Diagnostic Services at the Western College of Veterinary Medicine. Serum samples were analyzed for sodium, potassium, chloride, bicarbonate, anion gap, calcium, phosphorus (inorganic), magnesium, urea, creatinine, glucose, total protein, albumin and albumin:globulin ratio with the Boehringer-Mannheim Hitachi 912 Automatic Analyzer.

Professionals at the W.C.V.M., Sask Ag & Food and Lakeland Veterinary Clinic in North Battleford, SK were consulted in the analysis and interpretation of the data.

Samples of all feed ingredients fed to the cows at the time of incidence, including hay, greenfeed, barley, screenings and other supplements were collected from each farm and taken for analysis at EnviroTest Laboratories. The concentrate, hay and greenfeed

samples were digested with nitric-perchloric acid mixture prior to mineral analysis according to the method of AOAC (1990b). Crude protein was determined using the Kjeldahl method (AOAC, 1995), acid detergent fiber (ADF) using the Ankom® fiber analyzer (AOAC, 1990a), and moisture was calculated according to the methods of AOAC (1990c).

Water samples from each farm were also collected and analyzed for sulfate, chlorine, potassium, sodium and magnesium by ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry) analysis, the total dissolved solids (TDS) were calculated from electrical conductivity (EC x 670 = TDS mg/L), and copper nitrate and iron were analyzed according to procedures outlined in Standard Methods for the Examination of Water and Wastewater by the American Public Health Association (1999).

Interviews were conducted with the five producers of the experimental herds in order to determine the specific feed program of each herd for the months of December, January, February and March 2002, as well as other pertinent information including history of forage production, herd nutrition, symptoms and treatment of cows affected with hypomagnesemic tetany/milk fever. Using this information on feeding programs and the nutrient analysis of each feedstuff, complete rations were formulated using the Cowbytes™ Beef Ratio Balancer (Alberta Agriculture, 1999).

3.2 Results and Discussion

3.2.1 Feed Ration Analysis

In all five herds, cereal green-feeds (oat and barley) comprised the bulk of the cows' winter rations. The forages were cut in the early to soft dough stage and baled for greenfeed. All fields where forages were grown had nitrogen fertilizer application in the

spring prior to seeding, and one farm had applied manure heavily to the field as well.

Results from the feed analysis showed that potassium levels in these green-feeds ranged from 1.5 to 3.26% (Table 3.1), and many of them were higher than the average 1.49% potassium content of oat hay (NRC, 1996).

Table 3.1 Calcium, magnesium and potassium content (% DM basis) of greenfeed samples taken from five trial farms in the North Battleford area (Jan/Feb 2002).

Farm	Feed type	Ca	Mg	K
		%	%	%
A	Oat/Pea Greenfeed	0.36	0.25	2.30
B	Oat greenfeed	0.29	0.16	1.90
	Barley greenfeed	0.34	0.17	1.50
C	Barley greenfeed	0.28	0.19	2.05
	Oat greenfeed	0.37	0.24	3.26
D	Oat Greenfeed	0.32	0.20	2.40
E	Oat/barley greenfeed	0.24	0.19	2.22

Table 3.2 Mineral content of total dry cow rations (winter 2002) in five producer herds, expressed as percentages of total ration and amount consumed /head/day.

Farm	Ca		Mg		K	
	%	g/hd/day	%	g/hd/day	%	g/hd/day
A	0.68	105	0.22	34	1.53	236
B	0.65	95	0.20	30	1.91	278
C	0.33	52	0.18	28	2.16	336
D	0.41	61	0.17	25	1.29	190
E	0.33	48	0.18	27	1.41	207

The five feeding programs for the five herds for the month of January 2002 were entered into the Cowbytes Beef Ratio Balancer (Alberta Agriculture, 1999) and evaluated on the basis of DCAB (Dietary cation-anion balance), Ca:P and tetany ratios as well as total amounts of minerals in each ration. These rations were a 'snapshot' of the total ration, however, they represent a good estimate of the basic feed ration for each herd over the course of the winter and spring. (See Appendix A).

Table 3.3 The Ca:P ratio, DCAB and K/[Ca+Mg] ratios in the diets of gestating cows (winter 2002-02) in five producer herds in the North Battleford area, expressed on dry matter basis and including minerals consumed in water.

Farm	Ca:P		DCAB		K/(Ca+Mg)*	
	dry matter	with water	dry matter	with water	dry matter	with water
A	3.61	3.67	355	340	0.75	0.74
B	1.58	1.97	319	199	1.15	1.03
C	1.6	1.91	316	170	0.96	0.80
D	1.31	1.49	518	453	1.77	1.44
E	2.41	2.84	410	224	1	0.64

* Calculated using milliequivalents

The results of the diet analyses are shown in Table 3.3. The dietary cation-anion balance (DCAB), Ca:P and tetany ratios (K/[Ca+Mg) are expressed on both a dry matter basis as well as with the contribution of electrolytes from water. The tetany ratio of the diets (DM basis) ranged from 0.75 to 1.77, all well below 2.2 which is considered the 'safe' level. Simply looking at this result, there seems to be no obvious nutritional explanation that would be linked to the development of hypomagnesemic tetany. However, actual amounts of individual minerals may have played a part in the onset of the symptoms of disease. Although all rations contained less than the 3% potassium maximum on a dry matter basis (as per NRC recommendations), the actual amounts of potassium consumed by the animals ranged from 190 to 336 g/day (Table 3.2), which was two to three times higher than the requirement of approximately 90 g/day. Research by Goff and Horst (1997) found that increasing the dietary potassium to 2.1 or 3.1% increased the incidence of milk fever to 10 of 20 cows and 11 of 23 cows, respectively. Some research has shown that high potassium diets may cause interference with ruminal absorption of magnesium (Martens and Rayssiguier, 1980) and calcium (Goff and Horst, 1997), thus predisposing the animal to milk fever and hypomagnesemia.

Since potassium is a cation, excess amounts of potassium can also cause an increase in the cation-anion balance of the diet. It has been suggested that diets with a highly positive cation-anion difference may cause a state of metabolic alkalosis in cows, reducing the responsiveness of bone and kidney to PTH, and increasing the incidence of milk fever due to the reduced ability of the cow to mobilize calcium from bone stores and supply it to the blood (Goff and Horst, 1997).

The Ca:P ratios of the diets based on dry matter intake ranged from 1.58 to 3.61 (Table 3.3). All were within the acceptable range of 1.5 to 7 for beef cows (NRC, 1996) and did not appear to be the cause of the tetany-like problems observed in these herds.

Table 3.4. Water analysis from five producer farms in the North Battleford area.

Test	Farm				
	A	B	C	D	E
pH	6.9	7.3	6.9	7.1	7
Total dissolved solids (mg/L)	806	1152	1408	1830	1946
Calcium (mg/L)	49	185	320	318	443
Magnesium (mg/L)	15	66	137	151	227
Sodium (mg/L)	243	194	93.6	285	111
Potassim (mg/L)	7	8	8	13	11
Chloride (mg/L)	5	19	9	42	81
Sulfate (mg/L)	272	564	82	1095	1175
Nitrate (mg/L)	2.4	<1.0	<1.0	<1.0	93
Hardness (as $CaCO_3$)	183	735	1364	1416	2040
Iron (mg/L)	0.04	2.4	2.5	1.5	0.04

Water samples from each of the five farms were analyzed for total dissolved solids (TDS) and minerals (Table 3.4). The inclusion of minerals present in the water had a slight effect on the calculated value of the DCAB, Ca:P ratio and the tetany ratio (Table 3.3). The DCAB was decreased in all the herds assuming that the cows were drinking approximately 38 liters of water per day, however, most of the DCAB values were still

higher than the recommended level of +150 to +200 (Alberta Agriculture, 1999). The effect of water on the Ca:P ratio and tetany ratio was of no consequence or very minimal.

Interestingly, the dietary cation-anion balance (DCAB) of all five rations was quite high, ranging from 316 to 518 (Table 3.3). According to Cowbytes (Alberta Agriculture, 1999), DCAB values higher than +150 or +200 in beef cow diets present a higher risk for causing milk fever. As reviewed previously, diets with a highly positive cation-anion balance cause a state of metabolic alkalosis in cows reducing the responsiveness of bone and kidney to parathyroid hormone (PTH), and thus decreasing the mobilization of calcium which eventually results in hypocalcemia (Horst et al. 1997).

In this analysis, it was necessary to assume that each cow in the herd was consuming an equal portion of the ration and that consumption was constant throughout the feeding period.

3.2.2 Blood Analysis

The results from the blood serum tests are illustrated in Figures 3.1 to 3.11. These results showed that three of the five affected cows had low Ca and P (less than the normal values of 2.21 mmol/L and 1.45 mmol/L, respectively); one had normal Ca and low P; and one cow had normal levels for both Ca and P. Normal calcium values range from 2.0 to 2.74 mmol/L (Puls, 1988). The cows exhibiting low Ca ranged from 0.99 to 1.63 mmol/L, and the other two cows had values within the normal range, 2.48 and 2.27 mmol/L, respectively (Figure 3.1). Phosphorus levels ranged from 0.37 to 1.04 mmol/L (Figure 3.3) in four cows that were below the normal values of 1.45 to 2.26 mmol/L (Puls, 1988). One cow had a phosphorus value of 1.89 mmol/L which was within the normal range.

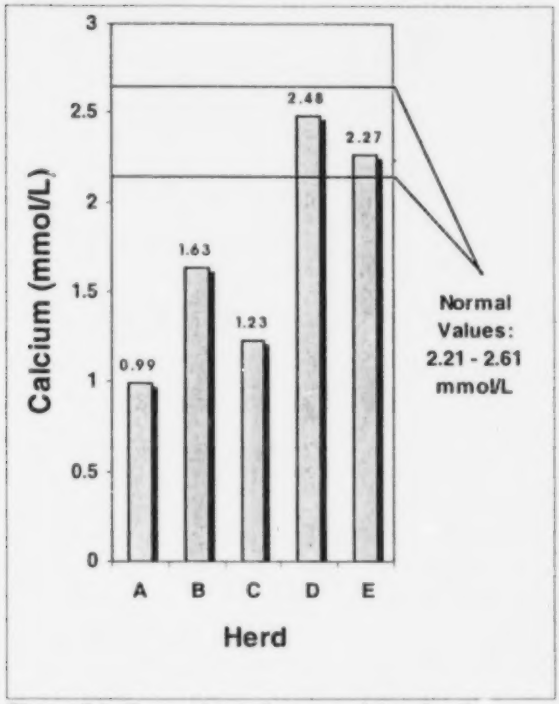

Figure 3.1 Comparison of serum calcium levels in affected cows with the normal range.

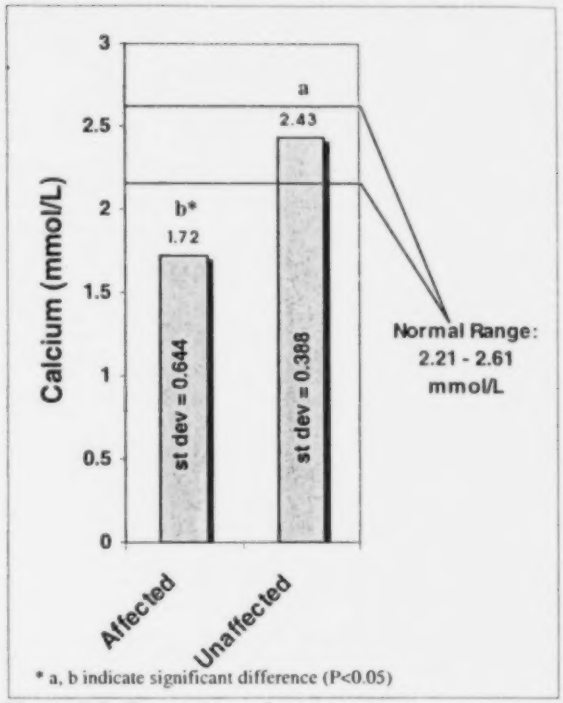

Figure 3.2 Comparison of average serum calcium levels in groups of affected and unaffected animals from five different herds.

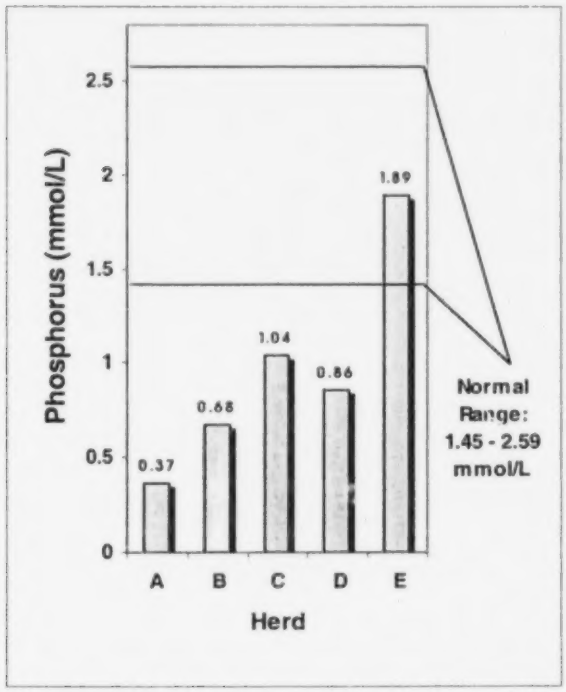

Figure 3.3 Comparison of serum phosphorus levels in affected cows with the normal range.

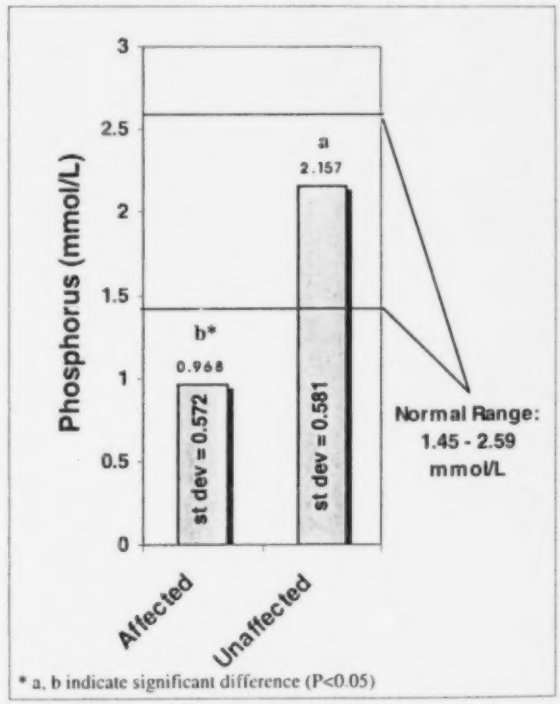

Figure 3.4. Comparison of average levels of serum phosphorus in affected and unaffected animals.

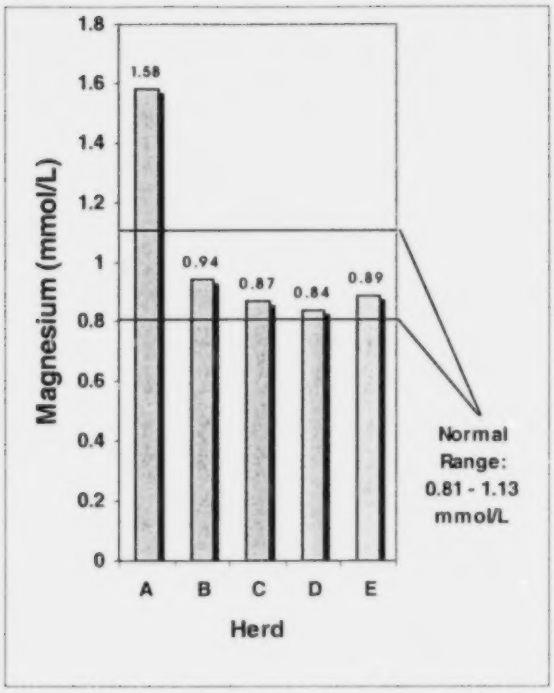

Figure 3.5 Comparison of serum levels of magnesium in affected cows with the normal range.

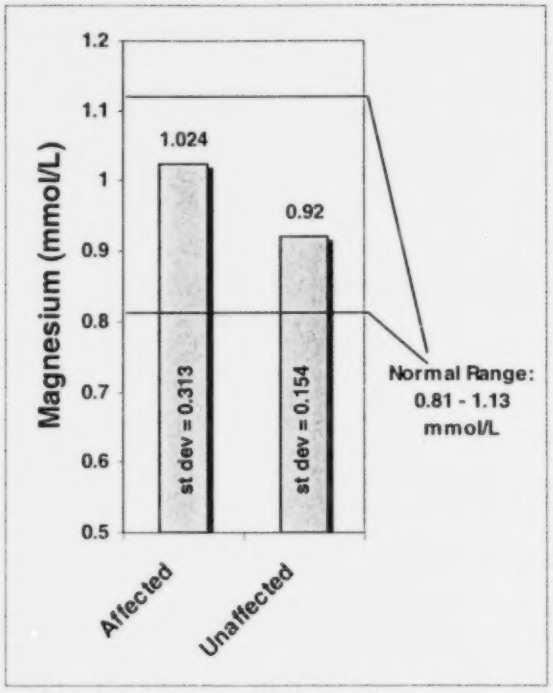

Figure 3.6 Comparison of average serum magnesium levels in affected and unaffected animals from five different herds.

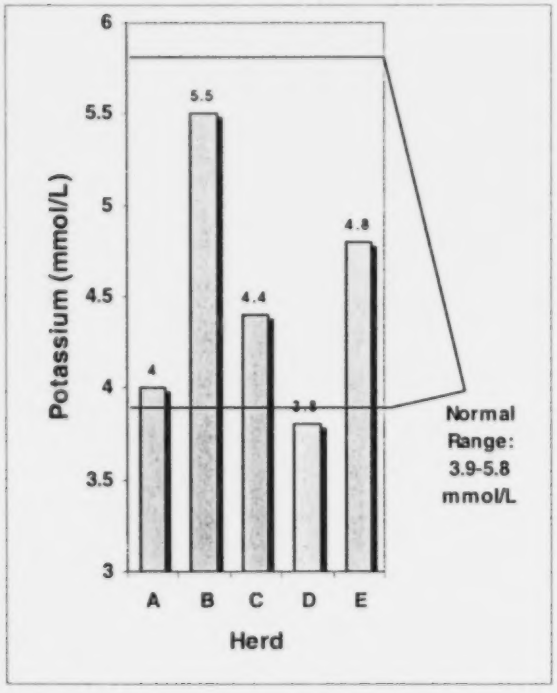

Figure 3.7 Comparison of serum levels of potassium in affected cows with the normal range.

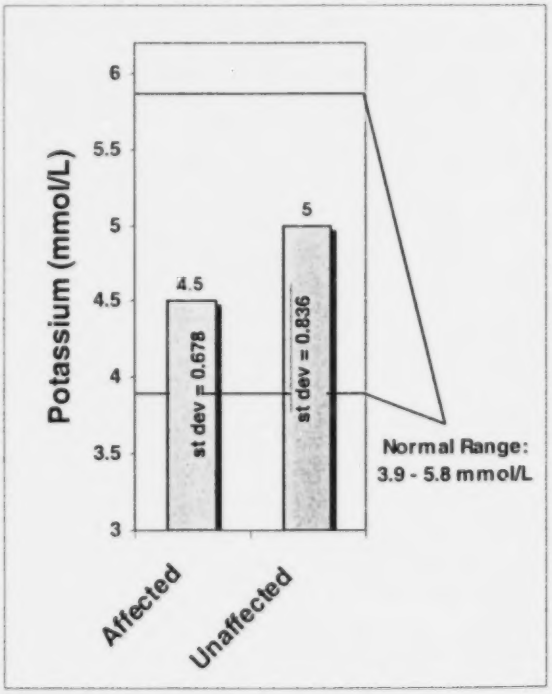

Figure 3.8 Comparison of average serum levels of potassium in affected and unaffected animals from five different herds.

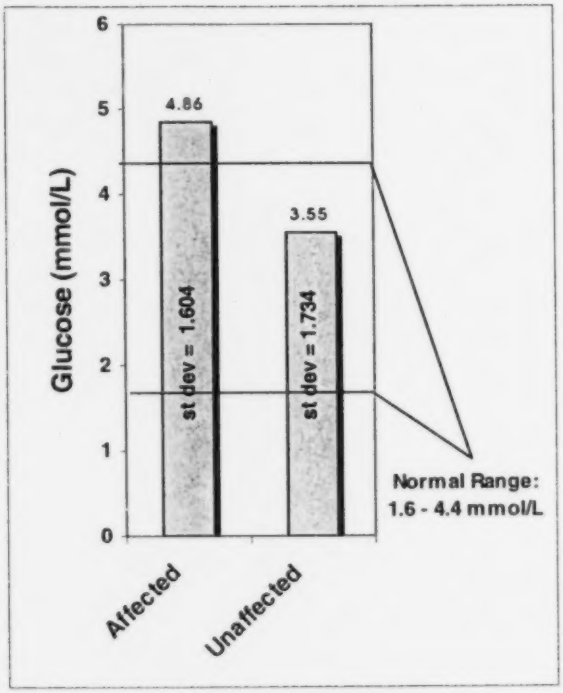

Figure 3.9 Comparison of average serum levels of glucose in affected and unaffected animals from five different herds.

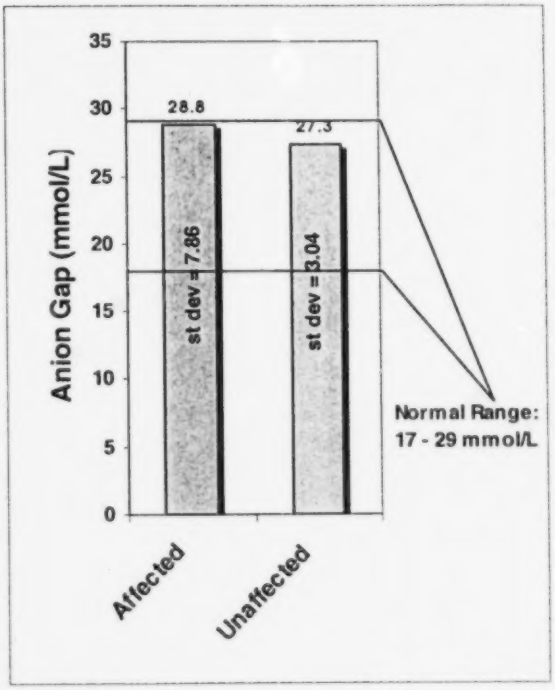

Figure 3.10 Comparison of average anion gap in affected and unaffected animals from five different herds.

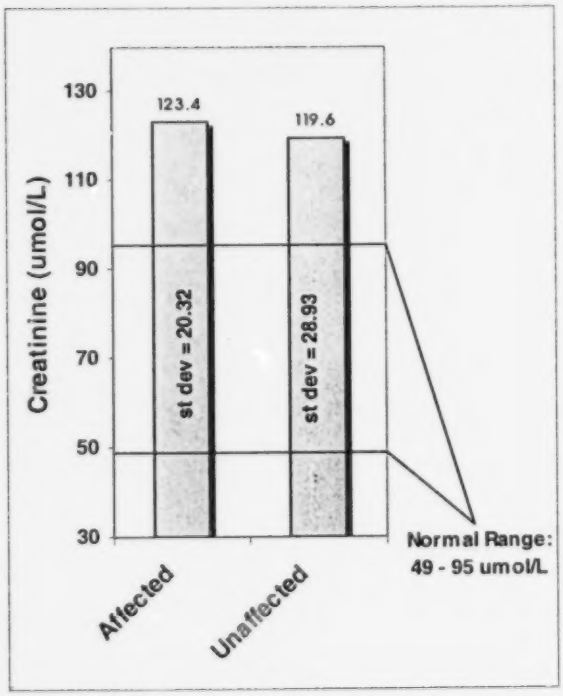

Figure 3.11 Comparison of average levels of serum creatinine in affected and unaffected animals from five different herds.

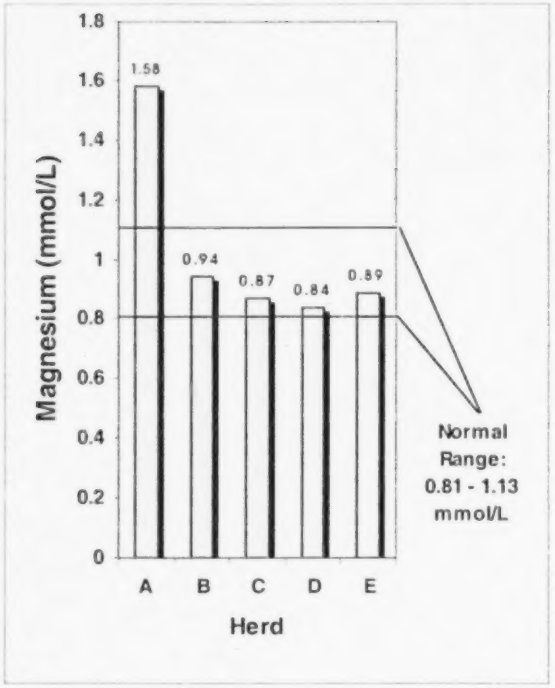

Figure 3.5 Comparison of serum levels of magnesium in affected cows with the normal range.

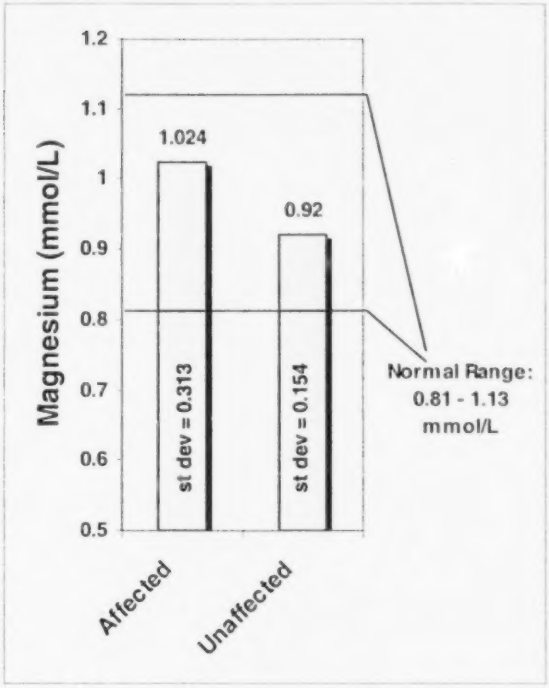

Figure 3.6 Comparison of average serum magnesium levels in affected and unaffected animals from five different herds.

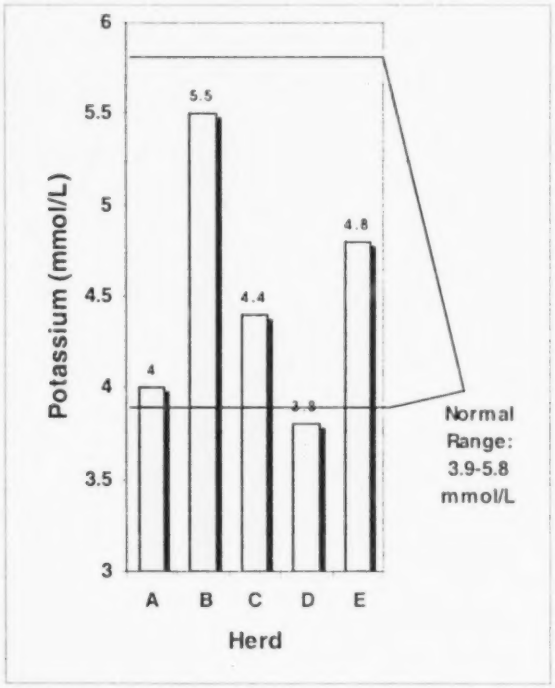

Figure 3.7 Comparison of serum levels of potassium in affected cows with the normal range.

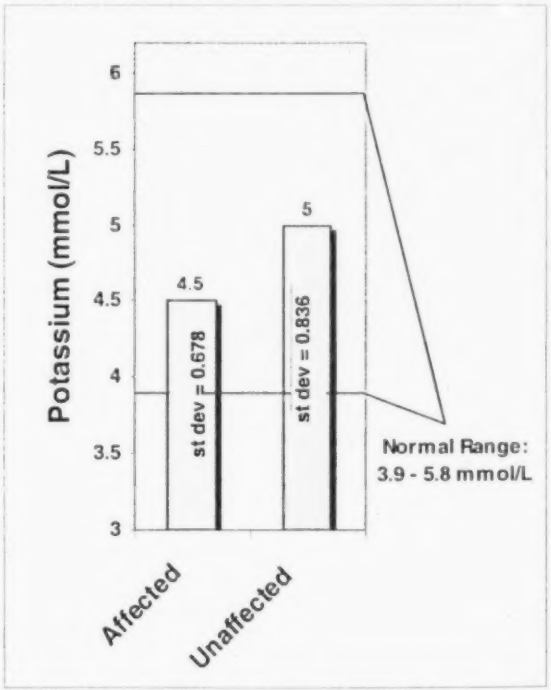

Figure 3.8 Comparison of average serum levels of potassium in affected and unaffected animals from five different herds.

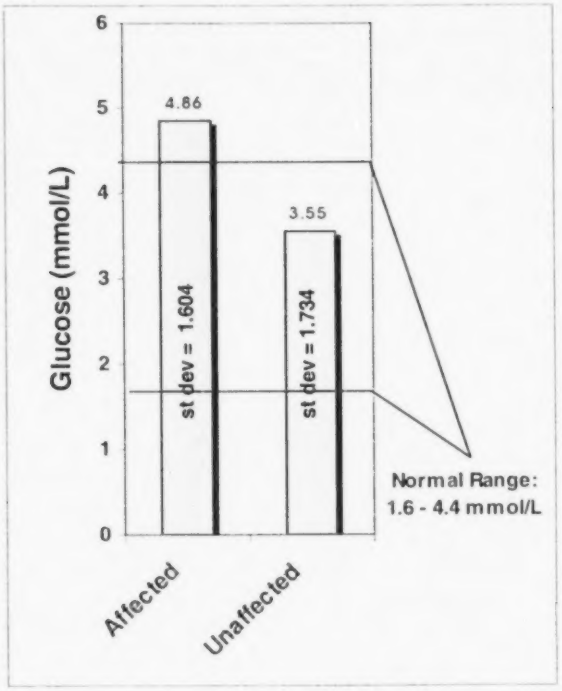

Figure 3.9 Comparison of average serum levels of glucose in affected and unaffected animals from five different herds.

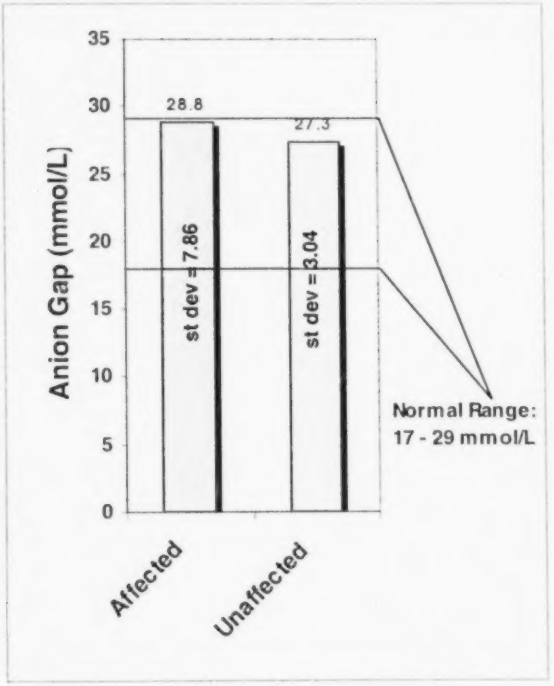

Figure 3.10 Comparison of average anion gap in affected and unaffected animals from five different herds.

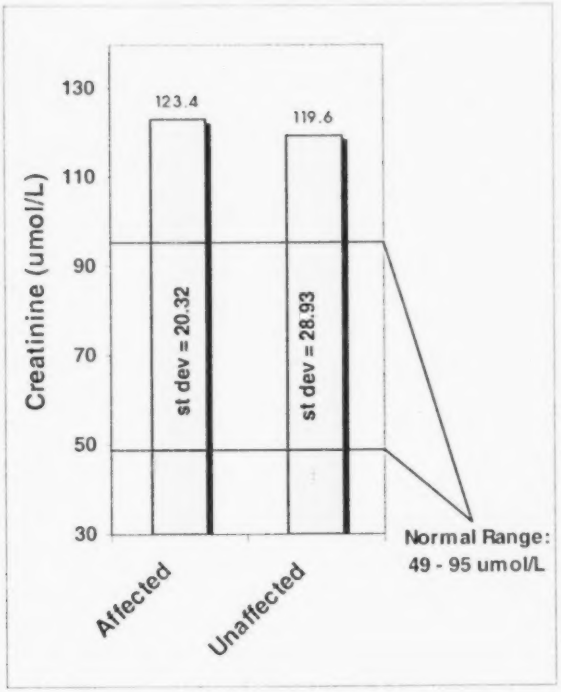

Figure 3.11 Comparison of average levels of serum creatinine in affected and unaffected animals from five different herds.

Statistical analysis showed that the affected cows had lower levels of both Ca and P than unaffected cows ($P < 0.05$). Table 6 shows that the average Ca and P serum concentrations of the five down cows were 1.72 and 0.968 mmol/L, respectively. These values were significantly lower than the normal range of 2.0 – 2.74 mmol/L. In comparison, the average values of calcium and phosphorus for the unaffected cows were within the normal range of 2.21 to 2.61 mmol/L (Table 3.5).

Table 3.5 Comparison of blood serum electrolyte levels in affected and non-affected cows.

	Blood serum levels of electrolytes (mmol/L)			
	K	Ca	Mg	P
Unaffected	5.02 ± 0.84	$2.43 \pm 0.39a$	0.92 ± 0.15	$2.16 \pm 0.58a$
Affected	4.50 ± 0.68	$1.72 \pm 0.64b$	1.02 ± 0.31	$0.97 \pm 0.57b$

a,b Means within columns followed by a different letter are significantly different ($P < 0.05$). (SNK test)

Interestingly, magnesium, ranging from 0.84 to 1.58 mmol/L, was normal to high for all affected cows (Figure 3.5), indicating that they were likely not suffering from hypomagnesemia. According to Blood et al. (1979), there is normally a rise in serum magnesium levels at calving, however, in cases where tetany is a feature, serum magnesium levels are below the normal range.

Potassium ranged from 3.8 to 5.5 mmol/L (Figure 3.7) and was also was within or very close the normal range – one value was 3.8 and only one tenth below the normal of 3.9 mmol/L. Average levels of magnesium and potassium were within the normal range for unaffected cows as well. Statistically, there was no difference in the average magnesium and potassium levels of affected and unaffected animals ($P > 0.05$) (Table 3.5).

These values seem to rule out the possibility of hypomagnesemic tetany and indicate that most of the affected cows likely suffered from hypocalcemia and hypophosphatemia, or milk fever. However, according to the attending veterinarian, the clinical symptoms at the time of treatment, such as increased muscle tone, labored breathing and lateral recumbancy in early stages, were not always consistent with milk fever, indicating that some other complications may have been occurring at the same time.

The one affected cow from herd E exhibited neither low calcium nor phosphorus and also exhibited normal levels of other serum electrolytes as well – there is a possibility that her case was complicated and may have been the result of some other problems. Sodium was normal in all affected animals and there was no difference between affected and unaffected groups. The average glucose levels in affected animals was higher than normal (Figure 3.9), however this is not suspicious, as stress caused by severe pain, sickness or forcible restraint is often associated with physiologic hyperglycemia (Kerr, 2002). This condition can be mediated by epinephrine which is produced in response to stress and opposes the action of insulin, thus increasing the serum glucose level. Cattle tend to experience marked stress hyperglycemia (Cornell University, 2002). The down cows in the present cases would most definitely be experiencing some form of stress, therefore, glucose may not an useful indicator of any underlying problems in this situation.

Another observation was that of high creatinine in many of the animals, both affected and unaffected (Figure 3.11). The average creatinine levels were 123.4 and 119.6 mmol/L for affected and unaffected groups, respectively. This could indicate

dehydration, which was certainly possible if the animals had been down or unable to walk to water for some time. Again, this parameter had poor diagnostic value as to the nature of the problems in this case. The average anion gap for groups of affected and unaffected animals was within the expected range of 17 to 19 mmol/L (Figure 3.10). Because the affected animals exhibited normal levels for this parameter, it likely rules out the incidence of metabolic acidosis as a cause of the tetany-like symptoms as this condition is typically indicated by an increased anion gap (Guyton and Hall, 2000).

Animal age also influenced the data. Mature cows (> 3 years and including affected cows) had significantly lower phosphorus than young cows ($P<0.05$), while there was no difference in calcium, potassium and magnesium (Table 3.6). Affected cows had significantly lower calcium than groups of both mature unaffected and young unaffected cows.

Table 3.6 Comparison of blood serum electrolytes in young (<3 years), mature (>3 years) and affected animals.

	Blood serum electrolyte levels (mmol/L)			
Group	K	Ca	Mg	P
Young cows	4.96 ± 0.76	2.61 ± 0.23*a*	0.96 ± 0.18	2.51 ± 0.47a
Mature cows	4.69 ± 0.53	2.34 ± 0.52*a*	0.87 ± 0.22	1.64 ± 0.68*b*
Affected cows	4.50 ± 0.68	1.72 ± 0.64b	1.02 ± 0.31	0.97 ± 0.57c

a,b Means within columns followed by a different letter are significantly different ($P < 0.05$). (SNK test).

3.3 Conclusion

It is necessary to keep in mind that the five herds used for this analysis were only a small sampling of the total number affected with milk fever and tetany-like symptoms in the spring of 2002. There are many variables to consider when trying to analyze the

problems, and coming up with a 'blanket statement' that covers all cases is difficult. However, there were several trends among the five herds that were of particular interest.

1. All farms fed a majority of the dry cow ration as cereal greenfeed.
2. Cows fed these rations would have been consuming excess amounts of potassium (measured in grams per day, not as a percentage).
3. All diets had significantly higher DCAB values than the recommended level, partially due to high potassium.
4. Most affected cows (of those tested) had low serum Ca, P or both, likely due to a combination of dietary and metabolic factors.
5. Treatment of affected cows required larger than normal doses of Ca/Mg/P solutions.

Hypomagnesemic (winter) tetany and milk fever are very complex diseases and are not always caused by one or two simple factors. There may well have been other nutritional, genetic or metabolic conditions that triggered the cases that were not even considered within the scope of this project. However, from the blood and feed data presented as well as clinical observations, it appears that the affected cows, at least in these five herds, were suffering from hypocalcemia or milk fever. Many of the physical signs observed in the affected cows were similar to those of both tetany and milk fever, but in general, most cases more closely resembled milk fever.

Feed analysis of the rations fed to the affected animals showed that the tetany ratio, K/(Ca+Mg), was within normal range and did not seem to indicate any risk. On the other hand, the DCAB was consistently high, indicating that the incidence of metabolic

alkalosis may have induced milk fever in the affected animals. Furthermore, the blood serum analysis of the affected cows showed that most had low calcium and phosphorus, most likely pointing to milk fever. If these cows were indeed suffering from tetany, it would be expected that the serum magnesium would have been low, but this was not the case. In fact, the serum magnesium levels in all affected cows was normal which suggests that they were not affected with tetany. Examination of physical symptoms, dietary parameters and blood serum electrolyte levels all seem to yield evidence that would support the conclusion that these cows were affected with milk fever rather than winter tetany.

It is possible that hypocalcemia in these cows was of alimentary or nutritional origin rather than related to parturition, especially in the cases which occurred several weeks prior to calving. A report by Hanif et al. (1990) investigated the occurrence of a hypocalcemic syndrome causing muscular weakness and recumbency observed in beef cattle in western Saskatchewan. The nature of the syndrome in beef cows was compared to that of milk fever (hypocalcemia) in dairy cows. This report found that both serum calcium and phosphorus in the beef cows were low, but suggested that it was due to alimentary factors rather than calcium depletion associated with parturition. They suggest that the observed hypocalcemia may be the result of decreased intestinal passage time of loose/watery feces. This would result in reduced absorption of calcium and phosphorus, thus predisposing to the occurrence of milk fever.

Potassium level in the feed by itself did seem to be connected to the occurrence of disease in the five cases examined in this project. The role of high potassium appears

to be related not to an increased tetany ratio as originally hypothesized, but to its contribution to an increased DCAB in the dry cow rations.

There is a limited amount of published information concerning the significance of high DCAB values for beef cattle. Extensive research has been conducted in reference to dairy cattle and recommendations for optimum dietary DCAB have been published, however, at present there are no formal recommendations as to an appropriate DCAB level for the diet of beef cattle. This is a possible area of further investigation which may yield valuable insight into the development of tetany-like symptoms in beef cows.

4.0 Research Project

4.1 Introduction

There has been a limited amount of research published in regard to the effects of the tetany ratio and dietary cation-anion balance in the feed ration of beef cattle. In light of the possibility of high levels of potassium accumulation in some cereal greenfeeds, it is of importance to determine what effects these parameters will have in cattle that are fed large amounts of greenfeed in the diet.

The objective of this experiment was to determine the relationship between the potassium content of the diet and the level of serum electrolytes, specifically, magnesium, potassium and calcium. By manipulating the chemical composition of the treatment diets, the effects of varying the tetany ratio and dietary cation-anion balance on blood serum electrolytes will also be studied. From these studies, any possible risk factors associated with feeding high potassium rations to beef cattle will be discussed as well as implications for beef producers.

4.2 Materials and Methods

4.2.1 Treatments

A 12-week feeding trial was conducted to determine the effect of the tetany ratio of the feed on blood serum electrolyte levels in beef steers. The experimental treatments consisted of four diets formulated with increasing amounts of potassium carbonate (K_2CO_3). Each diet consisted of 80% alfalfa-brome hay and 20% barley pellet. The composition of the barley pellet for each treatment was altered by the addition of feed grade potassium carbonate (K_2CO_3), in order to increase the tetany ratio [K/(Ca + Mg)].

DCAD Plus™ (56.6% potassium by weight) was the commercial product used to supply potassium in the form of potassium carbonate. This particular chemical compound was selected because it is chemically neutral and does not affect the acid/base balance of the rations. Table 8 shows the composition of the pellets for each of the four treatments.

The four treatment diets were formulated to have target tetany ratios of 0.92, 1.56, 2.20 and 2.84, respectively. The actual value of the tetany ratios for the four treatments were 0.82, 1.37, 1.91 and 2.78, respectively (Table 4.1). These varied somewhat from this target prediction due to variation in the nutrient composition of the hay and pellets after formulation. The control diet (Treatment 1) contained no added K_2CO_3 and consisted of 80% hay and 20% straight barley pellet. Molasses and tallow were added during the pelleting process to improve pellet binding, but neither contained any of the minerals of concern in this experiment (K, Mg, Ca, Cl, S, Na), and therefore did not affect the tetany ratio or the cation-anion balance.

Treatment 4, which contained the largest amount of potassium carbonate (18.2%), was specifically formulated to contain less than 3% total potassium, which is the maximum tolerable dietary concentration of potassium in cattle diets as specified by the NRC (1996). When the actual feed analysis was run, the potassium concentration of the sample was 3.46% (Table 4.2), based on dry matter fed. The calcium and phosphorus provided by the diets was in excess of the maintenance and growth requirement of the steers, although still well within the acceptable limits. According to NRC (1996), finishing cattle weighing approximately 450 kg and gaining 0.5 kg per day require 23 and 15 g of calcium and phosphorus per day, respectively for maintenance and growth. These

rations provide 0.13 to 0.15% magnesium which is very close to the requirement of 0.1% (NRC, 1996).

Table 4.1 Pellet composition of four experimental diets

Ingredient (%)	Pellet			
	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Barley	93.5	87.4	81.1	75.3
DCAD Plus (K_2CO_3)	0.0	6.1	12.4	18.2
Tallow	3.2	3.2	3.2	3.2
Molasses	3.3	3.3	3.3	3.3

Table 4.2 Mineral composition of total experimental diets (including both hay and pellet) expressed as percent dry matter and as gram per head per day of dry matter fed.

Treatment	Ca		Mg		K		P	
	%	g/hd/day	%	g/hd/day	%	g/hd/day	%	g/hd/day
1	0.44	45	0.15	15	1.08	112	0.2	21
2	0.41	42	0.14	14	1.73	178	0.2	20
3	0.41	42	0.14	14	2.37	243	0.19	20
4	0.41	42	0.13	14	3.46	354	0.18	18

Table 4.3 The Ca:P, DCAB and K/(Ca+Mg) ratios of the four experimental treatment diets.

Treatment	Ca:P	DCAB	K/(Ca+Mg)*
1	2.15	195	0.82
2	2.10	359	1.37
3	2.13	524	1.91
4	2.27	805	2.78

*calculated using milliequivalents

4.2.2 Steers

Sixteen yearling Hereford-cross steers (average weight = 518.7 kg) were weighed at the beginning of the trial and divided equally based on body weight into four groups of four steers. The average body weight of the four steers in each pen ranged from 517.8 to

519.4 kg. Each group was randomly assigned to one of the four treatments. During a 7-day transition period prior to the beginning of the trial, the steers received an 80% hay, 20% concentrate diet in order to accustom the animals to the high roughage diet. The steers were housed in 9 x 20 m outdoor pens at the University of Saskatchewan Feedlot, and were fed once daily at 8:30 am. The steers were fed *ad libitum*, however the amounts were adjusted to ensure that the steers ate all of their feed each day. A constant ratio of 80% hay: 20% pellet was maintained for all treatments, but total dry matter intake varied between treatments depending on how much feed each of the steers within the pen consumed. (ie. not all four treatment pens received the same amount of feed on a daily basis, but the ratio of minerals consumed was the same regardless of the level of consumption) After the first four weeks of the trial, all experimental treatments were consuming the same amount of feed on a daily basis (5 lbs pellet and 20 lbs hay per steer) and stabilized at this level for the remainder of the trial.

4.2.3 Data Collection and Analysis

Blood samples were taken five times during the trial in order to observe changes in serum electrolyte levels. These samples were taken approximately every 21 days, beginning on the first day of the trial (collection 1 = day 1; collection 2 = day 21; collection 3 = day 41; collection 4 = day 61; collection 5 = day 81). Two different analyses were done on the blood. These included large animal kidney/electrolyte fluid and blood gas analysis. Venous blood samples were obtained from each steer in 10mL red-top serum vacutainer tubes for the serum electrolyte analysis, and 2 mL heparin zed syringes for blood gas analysis. Samples were taken in the morning before feeding. The blood gas samples were cooled on ice immediately following collection and both red-top

serum and blood gas samples were taken to Prairie Diagnostic Services for analysis. Serum samples were analyzed for sodium, potassium, chloride, bicarbonate, anion gap, calcium, phosphorus (inorganic), magnesium, urea, creatinine, glucose, total protein, albumin and albumin:globulin ratio with the Boehringer-Mannheim Hitachi 912 Automatic Analyzer.

Samples of hay and pellets for each treatment were collected and taken for analysis at EnviroTest Laboratories, once at the beginning of the trial and again at the end. The hay and pellet samples were digested with nitric-perchloric acid mixture prior to mineral analysis according to the method of AOAC (1990b). Crude protein was determined using the Kjeldahl method (AOAC, 1995), acid detergent fiber (ADF) using the Ankom® fiber analyzer (AOAC, 1990a), and moisture according to the methods of AOAC (1990c).

Data collected from blood serum samples was analyzed using the SAS (Statistical Analysis System) program. Repeated measures analysis was run on the data to determine statistical significance of time and treatment as well as the time x treatment interaction.

4.2 Results and Discussion

Samples of hay and the pellets from each of the four rations were sent for nutrient analysis to determine the exact composition of each diet after pellet formulation. As seen in Table 4.3, the actual K/(Ca+Mg) ratios of the diets (0.82, 1.37, 1.91 and 2.78, respectively) varied somewhat from the predicted target values (0.92, 1.56, 2.20 and 2.84, respectively). The Ca:P ratio was fairly constant for all treatments which was to be expected due to the fact that only the amount of potassium was altered by the addition of potassium carbonate (K_2CO_3). The DCAB of the treatment diets increased from 195 in

Treatment 1 to 805 in Treatment 4, reflecting the increased concentration of potassium in the rations.

The purpose of feeding diets with varying tetany ratios was to monitor and track the effect of electrolytes in the diet on the electrolyte levels in the blood serum. This information would be of value to nutritionists and veterinarians who are concerned with the effects of such diets on the incidence of hypomagnesemic tetany or milk fever. A statistical summary of the effects of time and treatment on serum electrolytes is presented in Table 4.4. During the 12 week trial, none of the steers showed any physical signs of disease or appeared to be suffering from any mineral toxicity or deficiency.

Upon initial investigation, it appeared that feeding steers diets of varying tetany ratios had little or no effect on most serum electrolyte values. There was no significant treatment effect on potassium, but a linear effect of time ($P<0.01$) was observed. All treatments showed a trend of decreasing potassium in the serum over time (Figure 4.1). With the addition of potassium carbonate to the ration, it would be reasonable to predict that the absorption of potassium would increase accordingly. Greene et al. (1983a) reported that potassium retention increased when higher potassium levels were fed to steers and that serum potassium showed a linear increase with increasing levels on potassium in the diet. The observations of the present research do not agree as blood serum potassium decreased with time.

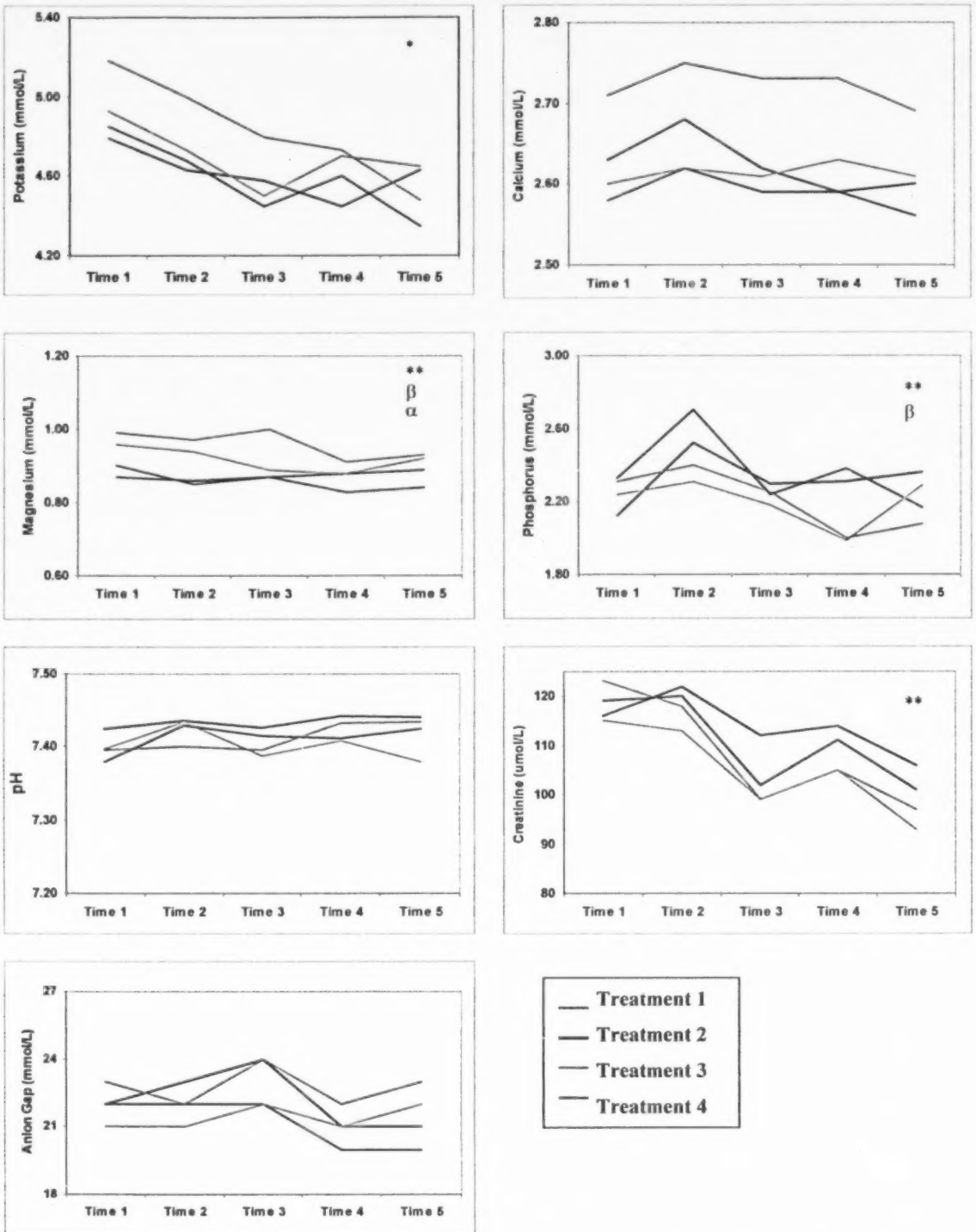

Figure 4.1 The effect of tetany ratio on serum electrolyte levels. * significant effect of time ($P < 0.01$); ** significant effect of time ($P < 0.001$); $^{\alpha}$ significant treatment effect ($P < 0.01$) ;$^{\beta}$ significant time x treatment interaction ($P < 0.05$). See Appendix B for least mean square values for each time period and treatment averages.

Table 4.4 Statistical results of repeated measures analysis indicating the effect of tetany ratio on blood serum electrolytes of beef steers.

P value	K	Ca	P	Mg	pH	Anion Gap (AG)	Creatinine (CT)
Treatment (trt)	NS	NS	NS	**	NS	NS	NS
Time	**	NS	***	**	NS	NS	***
Linear	**		*	**			***
Quadratic	NS		NS	NS			NS
Cubic	NS		***				NS
Trt * Time	NS	NS	*	*	NS	NS	NS

NS = P > 0.05; * P < 0.05; ** P < 0.01; *** P < 0.001

The tetany ratio of the feed did not produce any significant effects in serum calcium levels. Figure 4.1 illustrates that calcium remained relatively stable and constant throughout the trial period for all treatments and did not show any significant time-treatment interaction. Greene et al. (1983a) studied the effects of high levels of potassium fed to steers and reported that high potassium did not affect the balance and flow of calcium. The normal range for serum calcium is 2.21 to 2.62 mmol/L. Although fairly constant throughout the trial, the average calcium level of all four treatments was near the upper end of the normal range. Treatment 1 ranged from 2.59 to 2.68mmol/L, Treatment 2: 2.56 to 2.62 mmol/L; Treatment 3 – 2.69 to 2.75 mmol/L; and Treatment 4 – 2.60 to 2.63 mmol/L. Treatment 3 was slightly but consistently above the normal range.

Serum phosphorus was not significantly affected by treatment and there were no observable trends that appeared to be influenced by the tetany ratio. However, phosphorus did show a significant effect of time (P<0.001). During the 12 week trial, the serum phosphorus appeared to increase during the first 2 weeks, decrease in the following 3 to 4 weeks , and finally increase again near the end of the trial period. The normal range for serum phosphorus is 1.45 to 2.59 mmol/L. Even though a time effect was

observed, the average serum phosphorus levels for each treatment during each collection period remained within the normal range. The exception was collection period 2 for Treatment 2 in which the average phosphorus was recorded as 2.70 mmol/L. Hyperphosphatemia is most commonly associated with chronic renal failure (Kerr, 2002), however, the steers in this case were not experiencing any disorder of this nature. The slight increase in serum phosphorus was not at a level that would cause problems and did not persist for any length of time, returning to within the normal range at the time of the next collection date, indicating that it was a random and normal occurrence.

Normal serum magnesium levels range from 0.81 to 1.13 mmol/L, and the observed averages during each collection period for all treatments were within this range and showed no unusual fluctuations. Blood serum magnesium was significantly affected by both time ($P<0.01$) and treatment ($P<0.01$). There seemed to be a decreasing trend over time for Treatments 2, 3 and 4 and a constant or slightly increasing trend for Treatment 1. The time-treatment interaction was significant ($P<0.05$). It appeared that the Treatments with increasing tetany ratios (2, 3 and 4) all tended to cause a decrease in blood serum magnesium over time, while the control (Treatment 1) showed constant serum magnesium levels over time. This observation could be interpreted to indicate that increasing the tetany ratio does indeed reduce serum magnesium levels over time. However, the degree to which serum magnesium is affected does not necessarily appear to be proportional to the increase in the tetany ratio from the data presented in Figure 4.1. From these observations, it may be assumed that if the data was extrapolated, further increases in tetany ratio would cause serum magnesium to drop low enough to produce clinical symptoms of tetany. In the case of lactating cows, the stress of high magnesium

demands for milk production may be enough to cause clinical symptoms to occur. It is important to keep in mind that the high levels of potassium fed in these experimental rations (especially treatments 3 and 4) are not normal, and would not generally be encountered in most production situations, unless forages with high potassium content were being fed.

The normal blood pH of cattle ranges from 7.35 to 7.50 (Kaneko et al., 1997). From the experimental observations in this trial, the average blood pH of all steers in each treatment remained within this range and was not significantly affected by time or treatment. Disturbances of acid-base balance in the blood are classified in four general categories: respiratory acidosis, respiratory alkalosis, nonrespiratory (metabolic) acidosis and nonrespiratory alkalosis (Kaneko et al, 1997). Thus, deviation from normal blood pH may indicate the occurrence of acid-base imbalance, however, none of the steers in the trial exhibited abnormal pH values.

No significant time or treatment effects of tetany ratio in the diet on anion gap were observed. The normal anion gap in domestic animals falls between 17 and 29 mmol/L (Prairie Diagnostic Services, unpublished data) and the average anion gap of steers in all treatments was within this range for the duration of the experimental period. Increases in anion gap usually indicate an accumulation of unmeasured anions such as the accumulation of ketone anions in diabetes, lactate accumulation in shock or phosphate accumulation in uremia (Tasker, 1980). Decreased anion gap is less common, but may reflect hypercalcemia or hypoalbuminemia (Tasker, 1980).

Serum creatinine showed a significant ($P<0.001$) time effect. All four treatments exhibited a decreasing trend during the experimental period. Plasma concentrations under

150 µmol/L are normal for cattle and sheep and decreases are not clinically significant with regard to interpretation of plasma creatinine level (Kerr, 2002). Creatinine is a breakdown product of creatine, a substance present in muscle involved in high energy metabolism. There is a constant flow of creatinine into the blood due to normal muscle function, and changes in plasma creatinine concentration are almost solely due to renal excretion. Thus, increased creatinine may indicate kidney failure, however, the steers in this experiment were not affected by this.

The effect of varying the tetany ratio in the diet of steers on blood electrolyte levels seemed to have little overall effect as observed in this trial. Is there then a connection that can be noted between the tetany ratio of the diet and the incidence of tetany or milk fever-like symptoms in beef cattle? The apparent lack of response in the present trial may be explained by noting the primary metabolic differences between yearling steers and mature beef cows in late gestation or early lactation. Obviously, there are significant differences in nutrient requirements and demands in each case. For example, finishing cattle weighing approximately 450 kg and an average daily gain of 0.5 kg requires 23 g of calcium per day for maintenance and growth, while a mature cow in late gestation and early lactation requires between 29 and 36 g of calcium per day. Had cows been used in this trial, very different response to the treatments may have been observed. Cows in late gestation and early lactation experience a sudden demand for minerals such as calcium and magnesium to meet the demands of the fetus and for milk production. In addition, these steers were much younger than most cows that are commonly affected with tetany and milk fever symptoms. Similarly, the occurrence of grass tetany is much more common in older animals. The reason for this is that young

animals are better able to mobilize calcium and magnesium from their bones, and are therefore less likely to be affected with clinical symptoms of tetany-like diseases (Grunes et al. 1970; Fontenot 1979). Due to the fact that the steers in this trial were not experiencing any such sudden increase in demand for these minerals, no adverse effects from the tetany ratio or the DCAB of the diet were observed. However, that is not to say that increasing the tetany ratio and DCAB have no adverse effect on beef cattle. As seen in Figure 4.1, a decrease in serum magnesium is likely to occur with increasing tetany ratio, thus increasing the risk of tetany if allowed to drop below the normal range.

4.3 Conclusion

The results of this experiment indicate that varying the tetany ratio, [K/(Ca+Mg)], and the dietary cation-anion balance in the diet of steers did not significantly alter the level of blood serum electrolytes in beef steers. It appears that these diets did not predispose the steers to hypomagnesemia or hypocalcemia which are the primary factors involved in the cause of grass/winter tetany and milk fever. However, it is important to note that there was a significant time-treatment interaction ($P<0.05$) for blood serum magnesium which indicated that the levels decreased over time in steers fed rations with higher tetany ratios. This effect would likely be amplified in lactating cows that are under a certain amount of stress for magnesium, thus causing blood magnesium to drop significantly and predisposing them to tetany. A similar experiment conducted with mature gestating cows as the treatment animals instead of steers may yield significantly different results due to the metabolic and physiologic differences between these two groups of animals and their different mineral requirements.

5.0 Summary

Metabolic diseases such as milk fever and grass/winter tetany can present particular challenges to beef cattle producers, both from economic and animal welfare perspectives. In the past, relatively little research has been done regarding such metabolic diseases in relation to beef cattle. Many incidents were isolated and relatively rare, thus little emphasis was placed on discovering the underlying cause. In recent years, the prevalence of tetany-like symptoms in beef cattle has increased drastically in some areas of Saskatchewan. Investigation into the possible cause for this has led to closer examination of beef cattle rations and how they may be connected to the occurrence of tetany-like symptoms.

Milk fever and grass tetany (also known as winter tetany) are two metabolic diseases that produce tetany-like symptoms in cattle and are caused by hypocalcemia and hypomagnesemia, respectively. Blood serum concentration of electrolytes, such as calcium and magnesium as well as phosphorus, potassium and others, can be influenced by mineral levels in the diet. In addition, interaction between various electrolytes within the body can have an effect on the availability to the cow. Three important dietary ratios that have been identified are the tetany ratio, dietary cation-anion balance and the calcium: phosphorus ratio. These ratios may indicate certain mineral imbalances in the ration that may disrupt metabolic function in the cow. One particular interaction is that excess potassium will interfere with the absorption of magnesium in the rumen, thus reducing blood levels and the amount of magnesium available for bodily functions.

Certain environmental factors such as temperature, moisture conditions and soil type as well as maturity of the plant at harvest and rates of fertilization can all affect the mineral concentration of forage plants and thus the mineral ratios.

A field study of five beef herds in the North Battleford area was conducted to examine the blood electrolyte levels of affected and unaffected animals and their relationship to the particular feed ration of each herd. It was noted that in each of the herds, cereal greenfeed was the primary component of the ration. This was significant due to the fact that they commonly accumulate higher levels of potassium than legume forages such as alfalfa. Analysis of the rations indicated that they contained excess potassium on a dry matter basis and had DCAB values which were considerably higher than the recommended level, presumably due to the increased potassium content. Currently, beef producers have little information regarding the DCAB in gestating and lactating cow rations. It appears that increasing awareness of this problem may help to reduce the incidence of tetany-like symptoms in beef cattle.

From the observations of this field study, a research trial was conducted to evaluate the effect of varying the tetany ratio in the diet of beef steers on blood serum electrolyte levels. One primary observation was that of a decreasing trend of serum magnesium level with increasing tetany ratio. Although none of the steers had blood magnesium levels depressed far enough to cause clinical symptoms, this finding could be significant if the same treatment conditions were applied to cows.

The findings of this paper may have important applications for the beef cow producer. If diet is indeed a major factor in the cause of tetany-like symptoms observed in beef cattle, identification of ways to improve or manipulate the ration could reduce the

incidence of metabolic diseases such as milk fever and winter tetany in beef cows. Ultimately, this will improve the welfare of these animals as well as reducing the economic cost to the producer.

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APPENDIX A

Ration formulations (January 2002) for five producer herds in the North Battleford area.

Farm A

Feed	As Fed lbs/Head/Day	% of Ration
Oat/Pea Greenfeed	11.1	27.6
Slough Hay	19	47.2
Pea Chaff	6	14.9
16% VMR Pellet	4	9.9
CO-OP 1:1:1 mineral	0.06	0.1
Blue Salt	0.06	0.1
Total	40.22	

Nutrient (DM Basis)	Supplied	Recommended	Diet Concentration
DM Intake	33.9	34 lbs	84.2 %
DE	38.95	38.95 Mcal	1.18 Mcal/lb
TDN	19.99	19.52 lbs	58.99 %
NEm Total	18.09	18.09 Mcal	0.58 Mcal/lb
Neg	0.77	0.52 Mcal	0.32 Mcal/lb
Protein	1477	1106 g	9.6 %
Calcium	105	33 g	0.68 %
Phosphorus	29	21 g	0.19 %
Magnesium	34	19 g	0.22 %
Potassium	236	93 g	1.53 %
Sulphur	25	23 g	0.16 %
Sodium	23	12 g	0.15 %
Salt	34	31 g	0.22 %
Vitamin A	48607	43245 IU	3.2 KIU/kg
Vitamin E	49	60 IU	3 IU/kg
Copper	155	154 mg	10 mg/kg
Manganese	653	618 mg	43 mg/kg
Zinc	550	589 mg	36 mg/kg
Selenium	3.07	2.93 mg	0.2 mg/kg
Iodine	9.5	7.7 mg	0.6 mg/kg
Cobalt	27.7	7.7 mg	1.8 mg/kg
Iron	2568	772 mg	167 mg/kg
Molybdenum	26		2 mg/kg
NDF	61.5		61.5
eNDF	53.8	20 %	53.8 % of NDF
DIP	1081	1000 g	73.2 % of CP
UIP	396	109 g	26.8 % of CP
MP	1009	725 g	

Farm B

Feed	As Fed lbs/Head/Day	% of Ration
Barley Greenfeed	9.68	25.9
Oat Greenfeed	9.68	25.9
Barley Straw	9.7	26
Barley/Oat Grain	4	10.7
16% Lick Tub	0.25	0.7
16% VMR Pellet	4	10.7
Blue Salt	0.06	0.2
Total	37.36	

Nutrient (DM Basis)	Supplied	Recommended		Diet Concentration	
DM Intake	33.9	34	lbs	86.8	%
DE	38.95	33.7	Mcal	1.23	Mcal/lb
TDN	19.99	16.88	lbs	61.83	%
NEm Total	18.09	15.88	Mcal	0.61	Mcal/lb
Neg	0.77	0.52	Mcal	0.35	Mcal/lb
Protein	1477	1000	g	10.2	%
Calcium	105	33	g	0.33	%
Phosphorus	29	21	g	0.21	%
Magnesium	34	19	g	0.18	%
Potassium	236	93	g	1.41	%
Sulphur	25	23	g	0.16	%
Sodium	23	12	g	0.14	%
Salt	34	31	g	0.21	%
Vitamin A	48607	43245	IU	5.8	KIU/kg
Vitamin E	49	60	IU	4	IU/kg
Copper	155	154	mg	6	mg/kg
Manganese	653	618	mg	26	mg/kg
Zinc	550	602	mg	34	mg/kg
Selenium	3.07	2.93	mg	0.18	mg/kg
Iodine	9.5	7.7	mg	0.5	mg/kg
Cobalt	27.7	7.7	mg	1.3	mg/kg
Iron	2568	772	mg	184	mg/kg
Molybdenum	26			2	mg/kg
NDF	61.5			55	%
eNDF	53.8	20.00%	%	49.9	% of NDF
DIP	1081	1000 g	g	65.8	% of CP
UIP	396	0 g	g	34.2	% of CP
MP	1009	620 g	g		

Farm C

Feed	As Fed lbs/Head/Day	% of Ration
Alfalfa-Grass Hay	1.71	4.7
Barley Greenfeed	3.43	9.4
Oat Greenfeed	3.43	9.4
Slough Hay	1.7	4.7
Cereal Straw	11	30.3
Oat Grain	10	27.5
Oat Pellet Mix	5	13.8
Salt	0.06	0.2
Total	36.34	

Nutrient (DM Basis)	Supplied	Recommended	Diet Concentration
DM Intake	33.9	34.7 lbs	89.4 %
DE	38.95	37.9 Mcal	1.28 Mcal/lb
TDN	19.99	18.99 lbs	64.11 %
NEm Total	18.09	18.27 Mcal	0.65 Mcal/lb
Neg	0.77	0.52 Mcal	0.38 Mcal/lb
Protein	1477	1115 g	9.8 %
Calcium	105	33 g	0.41 %
Phosphorus	29	21 g	0.26 %
Magnesium	34	19 g	0.17 %
Potassium	236	93 g	1.29 %
Sulphur	25	23 g	0.13 %
Sodium	23	12 g	0.16 %
Salt	34	31 g	0.22 %
Vitamin A	48607	43245 IU	3.3 KIU/kg
Vitamin E	49	60 IU	5 IU/kg
Copper	155	154 mg	8 mg/kg
Manganese	653	630 mg	31 mg/kg
Zinc	550	614 mg	33 mg/kg
Selenium	3.07	2.93 mg	0.39 mg/kg
Iodine	9.5	7.7 mg	0.6 mg/kg
Cobalt	27.7	7.7 mg	1.3 mg/kg
Iron	2568	772 mg	151 mg/kg
Molybdenum	26		2 mg/kg
NDF	61.5		0.505 %
eNDF	53.8	20 %	41.6 % of NDF
DIP	1081	1000 g	69.2 % of CP
UIP	396	75 g	30.8 % of CP
MP	1009	725 g	

Farm D

Feed	As Fed lbs/Head/Day	% of Ration
Oat Greenfeed (tub-grind)	37	92.1
Barley Straw	3	7.5
18:18 Mineral	0.12	0.3
Blue Salt	0.07	0.2
Total	40.19	

Nutrient (DM Basis)	Supplied	Recommended	Diet Concentration
DM Intake	33.9	34 lbs	85.6 %
DE	38.95	34.26 Mcal	1.22 Mcal/lb
TDN	19.99	17.17 lbs	61.3 %
NEm Total	18.09	16.25 Mcal	0.61 Mcal/lb
Neg	0.77	0.52 Mcal	0.35 Mcal/lb
Protein	1477	1052 g	9.8 %
Calcium	105	34 g	0.33 %
Phosphorus	29	22 g	0.25 %
Magnesium	34	19 g	0.18 %
Potassium	236	93 g	2.16 %
Sulphur	25	23 g	0.18 %
Sodium	23	12 g	0.19 %
Salt	34	31 g	0.2 %
Vitamin A	48607	43191 IU	1.7 KIU/kg
Vitamin E	49	60 IU	2 IU/kg
Copper	155	154 mg	16 mg/kg
Manganese	653	617 mg	57 mg/kg
Zinc	550	602 mg	58 mg/kg
Selenium	3.07	2.93 mg	0.27 mg/kg
Iodine	9.5	7.7 mg	0.5 mg/kg
Cobalt	27.7	7.7 mg	2 mg/kg
Iron	2568	771 mg	182 mg/kg
Molybdenum	26		2 mg/kg
NDF	61.5		61.4 %
eNDF	53.8	20 %	60.2 % of NDF
DIP	1081	1052 g	68.8 % of CP
UIP	396	0 g	31.2 % of CP
MP	1009	634 g	

Farm E

Feed	As Fed lbs/Head/Day	% of Ration
Oat/Barley Greenfeed	30.14	79.9
16% VMR Pellet	7.5	19.9
Blue Salt	0.06	0.2
Total	37.7	

Nutrient (DM Basis)	Supplied	Recommended	Diet Concentration
DM Intake	33.9	35.2 lbs	85.3 %
DE	38.95	33.43 Mcal	1.3 Mcal/lb
TDN	19.99	16.75 lbs	65.34 %
NEm Total	18.09	16.35 Mcal	0.67 Mcal/lb
Neg	0.77	0.52 Mcal	0.4 Mcal/lb
Protein	1477	1238 g	9 %
Calcium	105	34 g	0.65 %
Phosphorus	29	22 g	0.27 %
Magnesium	34	19 g	0.2 %
Potassium	236	96 g	1.91 %
Sulphur	25	24 g	0.21 %
Sodium	23	13 g	0.13 %
Salt	34	32 g	0.24 %
Vitamin A	48607	44769 IU	4.7 KIU/kg
Vitamin E	49	60 IU	5 IU/kg
Copper	155	160 mg	6 mg/kg
Manganese	653	640 mg	28 mg/kg
Zinc	550	624 mg	23 mg/kg
Selenium	3.07	3.04 mg	0.23 mg/kg
Iodine	9.5	8 mg	0.8 mg/kg
Cobalt	27.7	8 mg	1.3 mg/kg
Iron	2568	799 mg	197 mg/kg
Molybdenum	26		3 mg/kg
NDF	61.5		51.6 %
eNDF	53.8	20 %	44.6 % of NDF
DIP	1081	1238 g	72.1 % of CP
UIP	396	0 g	27.9 % of CP
MP	1009	634 g	

APPENDIX B

Least Squares Means of blood serum parameters of four treatments groups of beef steers (n=4) at each measuring period during the experimental trial. Period 1 = day 1, Period 2 = day 21, Period 3 = day 41, Period 4 = day 61, Period 5 = day 81.

Treatment	Period 1	Period 2	Period 3	Period 4	Period 5
			Potassium (mmol/L)		
1	4.79	4.63	4.58	4.45	4.63
2	4.85	4.68	4.45	4.60	4.35
3	5.18	5.00	4.80	4.73	4.48
4	4.93	4.73	4.50	4.70	4.65
			Calcium (mmol/L)		
1	2.63	2.68	2.62	2.59	2.60
2	2.58	2.62	2.59	2.59	2.56
3	2.71	2.75	2.73	2.73	2.69
4	2.60	2.62	2.61	2.63	2.61
			Phosphorus (mmol/L)		
1	2.12	2.52	2.30	2.31	2.36
2	2.33	2.70	2.24	2.38	2.17
3	2.31	2.40	2.25	2.00	2.08
4	2.24	2.31	2.18	1.99	2.29
			Magnesium (mmol/L)		
1	0.87	0.86	0.87	0.88	0.89
2	0.90	0.85	0.87	0.83	0.84
3	0.99	0.97	1.00	0.91	0.93
4	0.96	0.94	0.89	0.88	0.92
			pH		
1	7.425	7.436	7.427	7.443	7.441
2	7.379	7.429	7.415	7.411	7.425
3	7.396	7.401	7.396	7.432	7.435
4	7.397	7.434	7.388	7.409	7.379
			Anion Gap(mmol/L)		
1	22	23	24	21	21
2	22	22	22	20	20
3	23	22	24	22	23
4	21	21	22	21	22
			Creatinine (umol/L)		
1	116	122	112	114	106
2	119	120	102	111	101
3	123	118	99	105	97
4	115	113	99	105	93

*This trial was carried out over the period from July 5 to October 1, 2002.